PID system for SPD

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December 2, 2020
SPD meeting

PID system of SPD

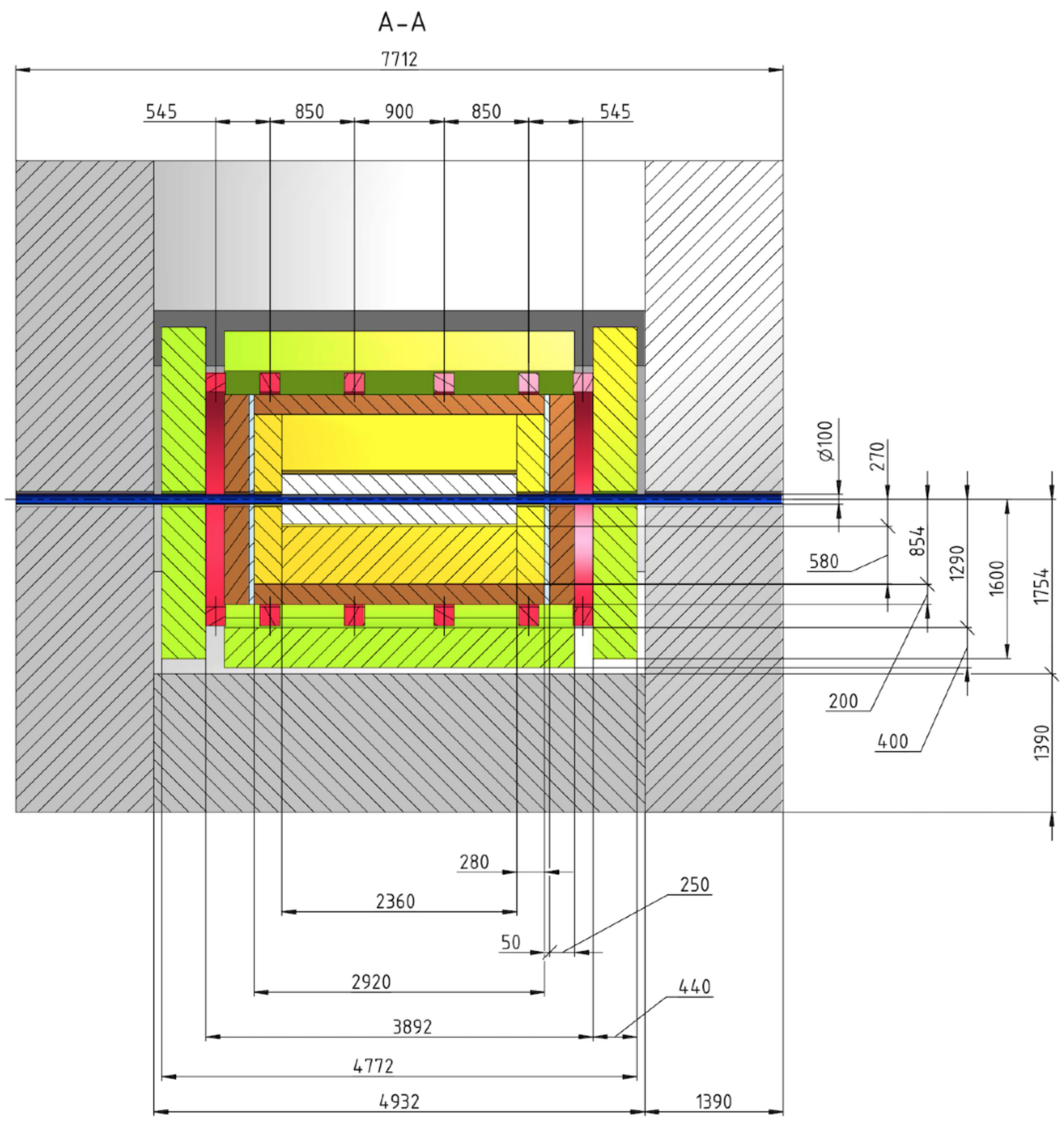
- Time-of-flight detector (+BBC/MCP of inner part)
- Aerogel detector
- Energy loss dE/dx in straw
- EM calorimeter
- Range system (hadron calorimeter)

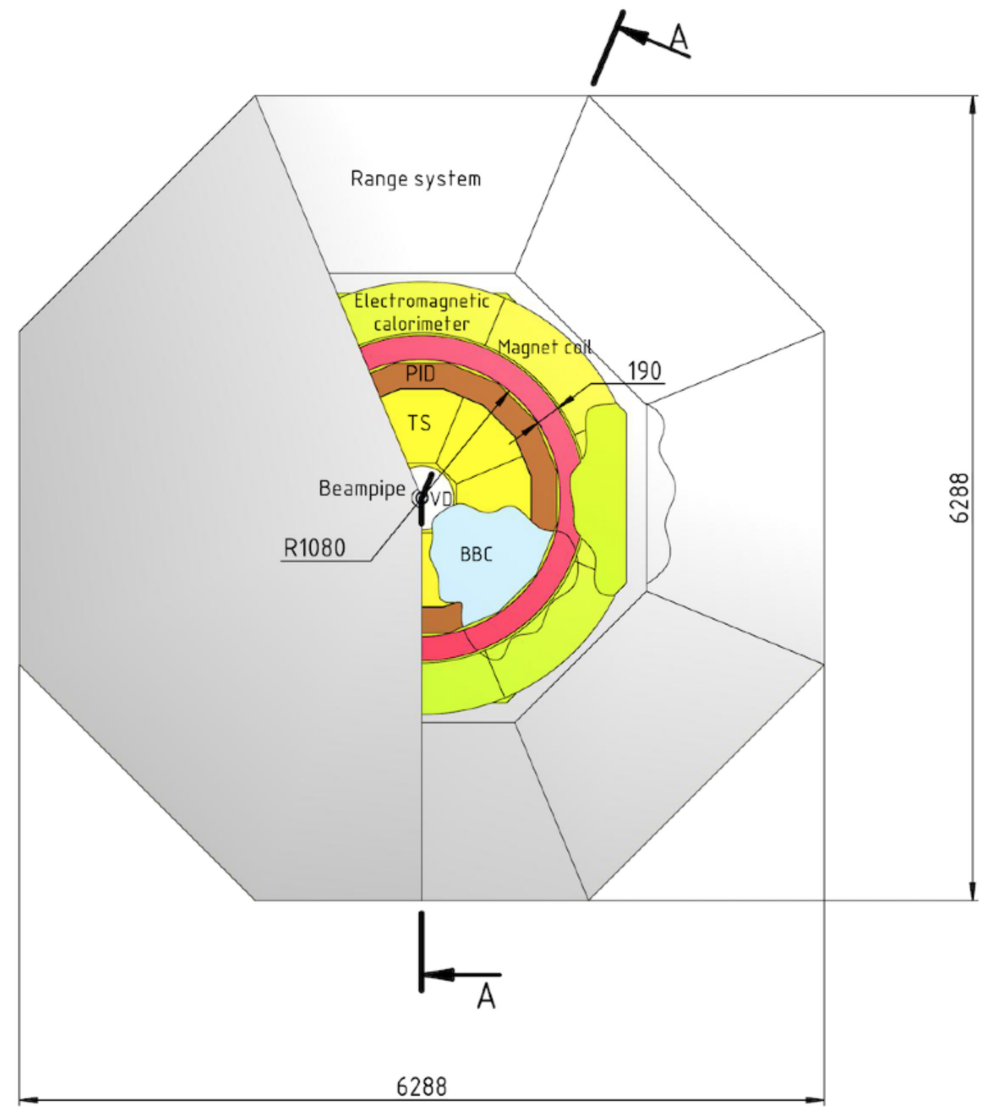
Table 4.1: Required setup configuration for each point of the SPD physics program. (+++) - absolutely needed, (++) - extremely useful, (+) - useful, (-) - not needed.

Program	Vertex detector	Straw tracker	PID system	Electromagnetic calorimeter	Beam-beam counter	Range system
Gluon content with:						
charmonia	+	++	-	++	-	+++
open charm	+++	++	++	-	-	+
prompt photons	+	+	-	++	-	-
SSA for π and K	+	++	+++	++	-	-
Light vector meson production	+	++	-	+	-	-
Elastic scattering	+	++	-	-	+++	-
$\bar{p}$ production	+	++	+++	++	-	-
Physics with light ions	++	+++	+	++	+	-

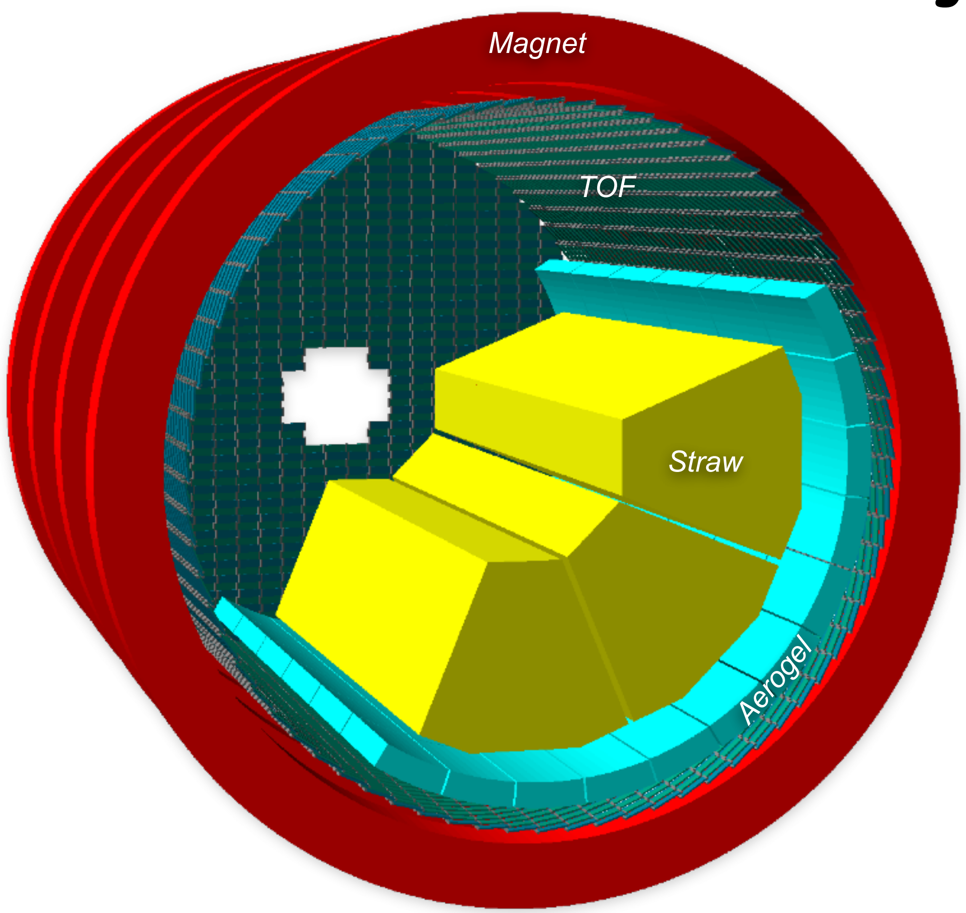
Detector position and dimensions (CDR, end of 2020)

20 cm gap between the straw tubes and the magnet coils



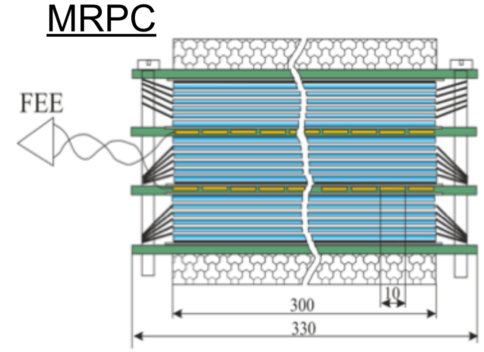


PID system of SPD (possible options)



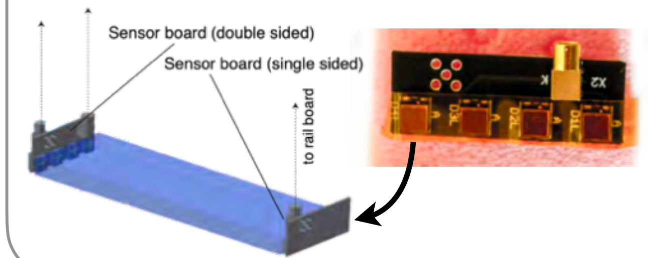
Time-of-Flight system (TOF)

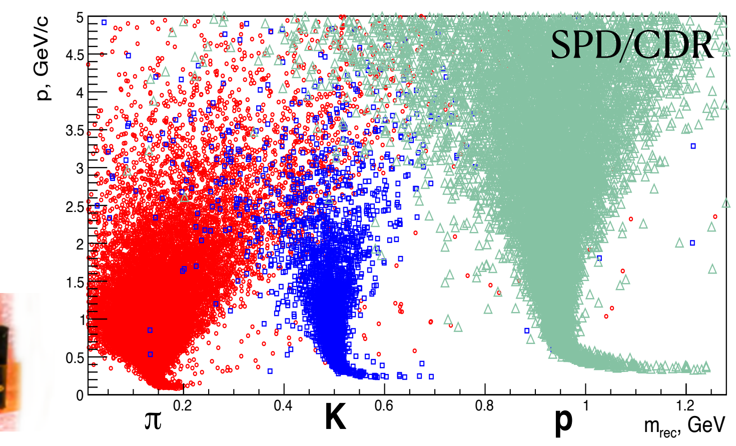
MRPC



For MRPC see TOF-TDR of MPD/NICA
For SciTil see TOF-TDR of PANDA

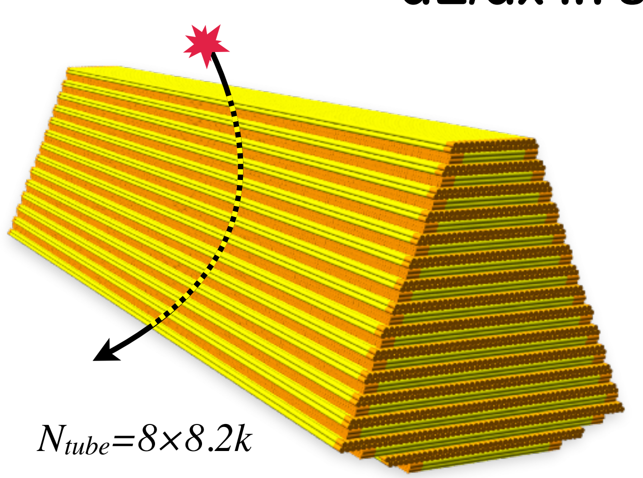
Scintillator Tile (SciTil)

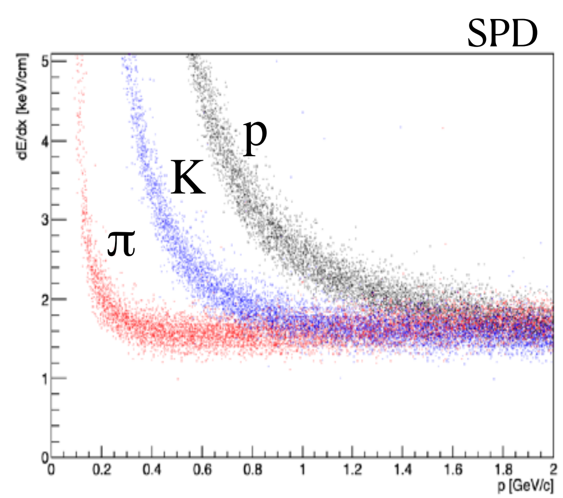




70ps resolution was assumed

dE/dx in straw tubes





60 layers = 30 (Z), 30 (Tang). Radially: 86cm - 27cm = 59cm

Aerogel (threshold counter)

Детектор КЕДР, ФЭЧАЯ 2003 т.44 вып.4

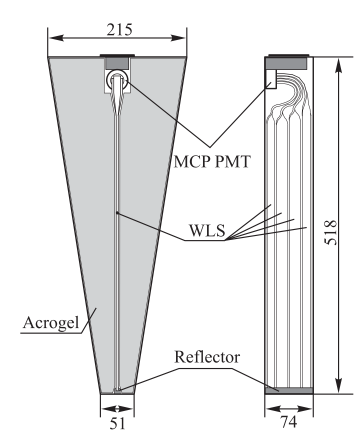


Рис. 16. Торцевой счетчик

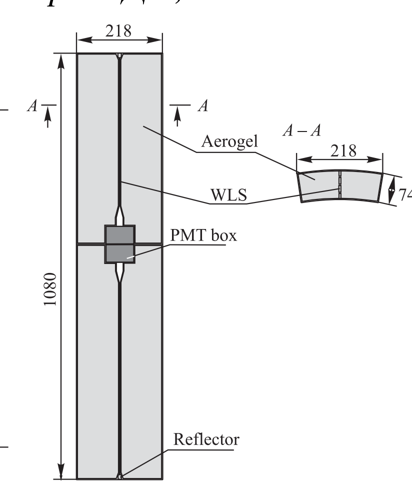


Рис. 17. Два баррельных счетчика в одном корпусе

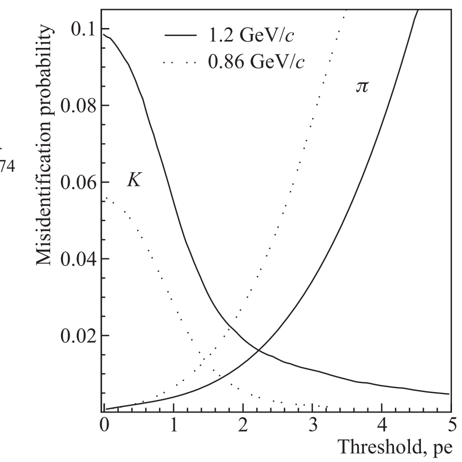
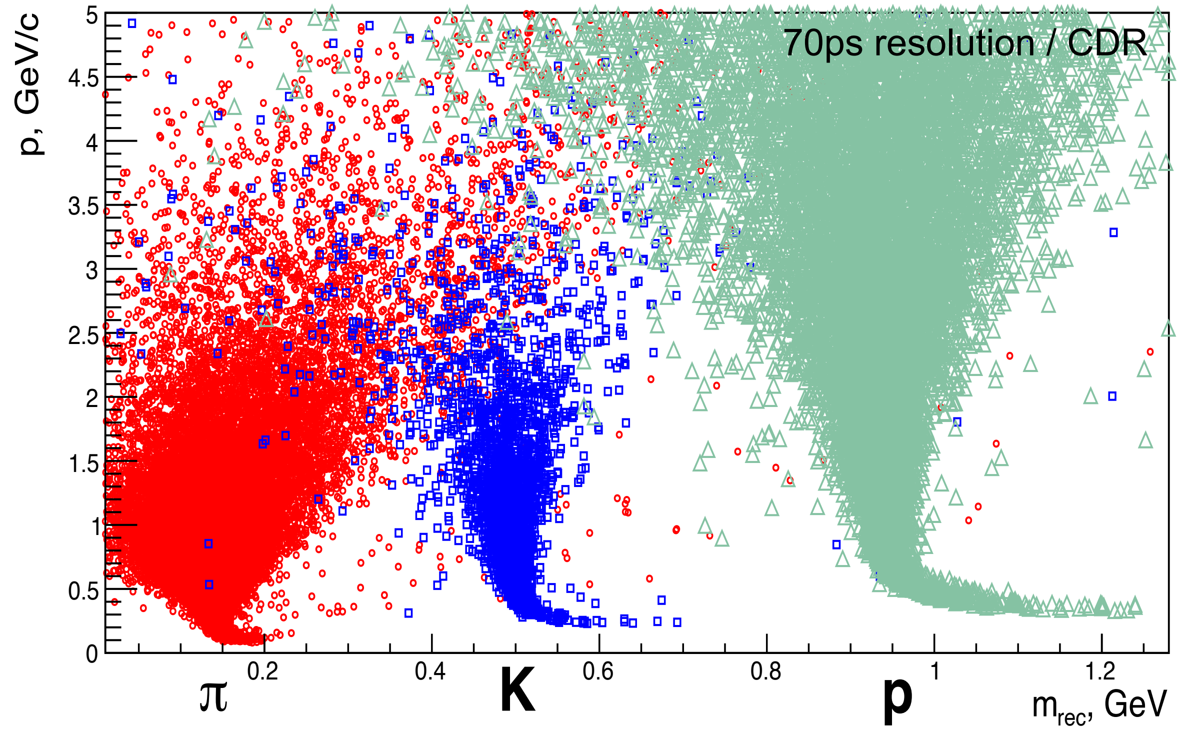


Рис. 20. Измеренная зависимость ложной идентификации пионов и каонов от амплитуды для импульсов $P = 0{,}86$ ГэВ/c и $P = 1{,}2$ ГэВ/c

6 p.e. per counter on average

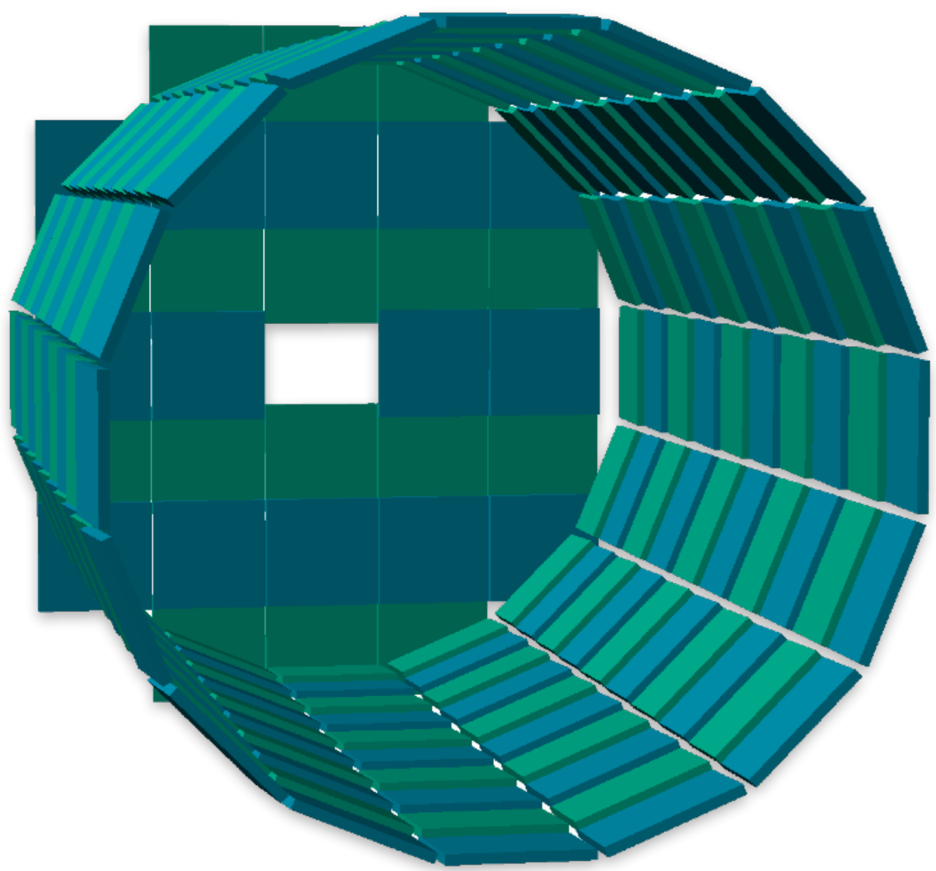
Time-of-flight (TOF) detector

- Particle Identification
- t_{start} for drift detector (straw)
- Combinatorial background suppression (76ns between bunches)

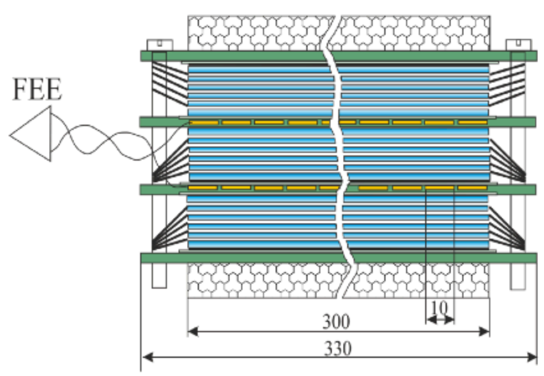


Two options for the TOF barrel of SPD (σ_t<70ps)

mRPC option

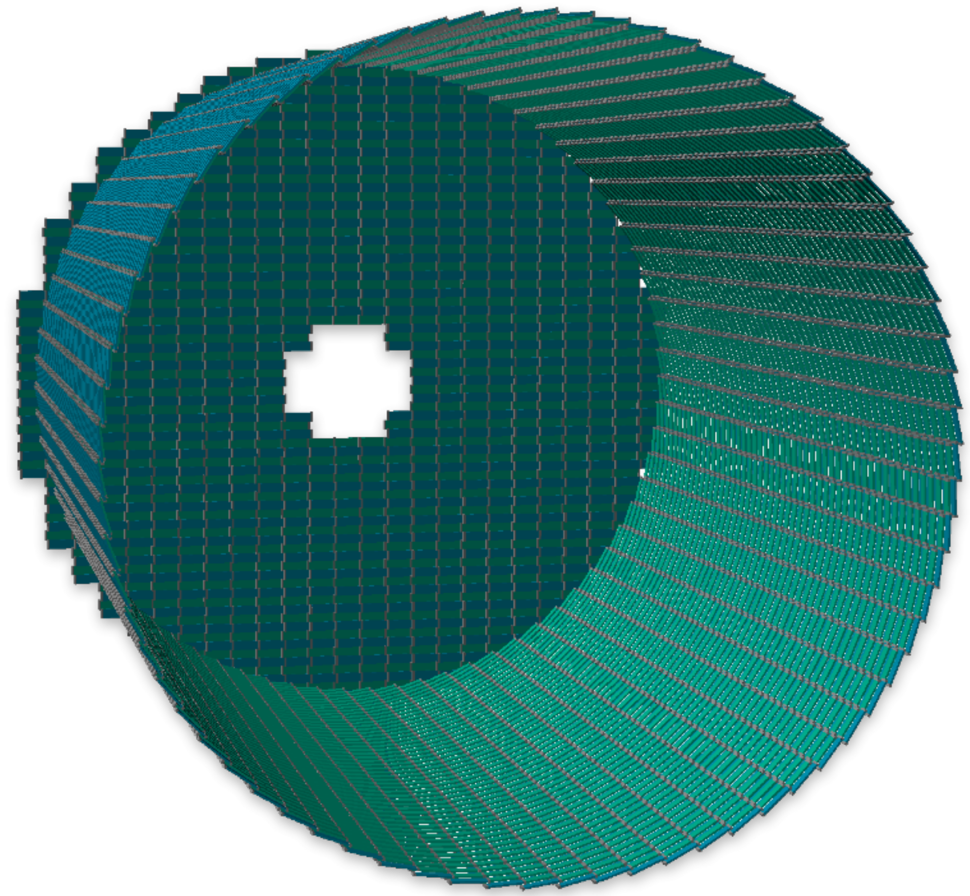


Inspired by the TOF MPD

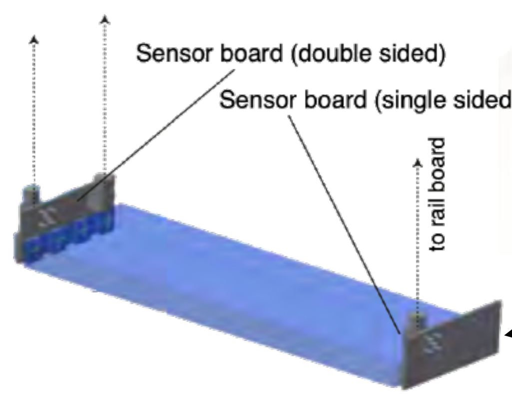


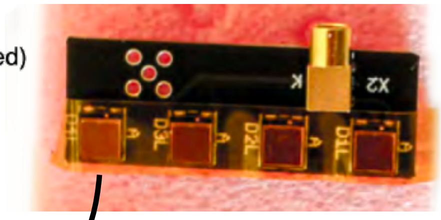
MPD NICA TDR TOF, Nov 2018, Rev 3.0

Plastic scintillator option



Inspired by the TOF of PANDA

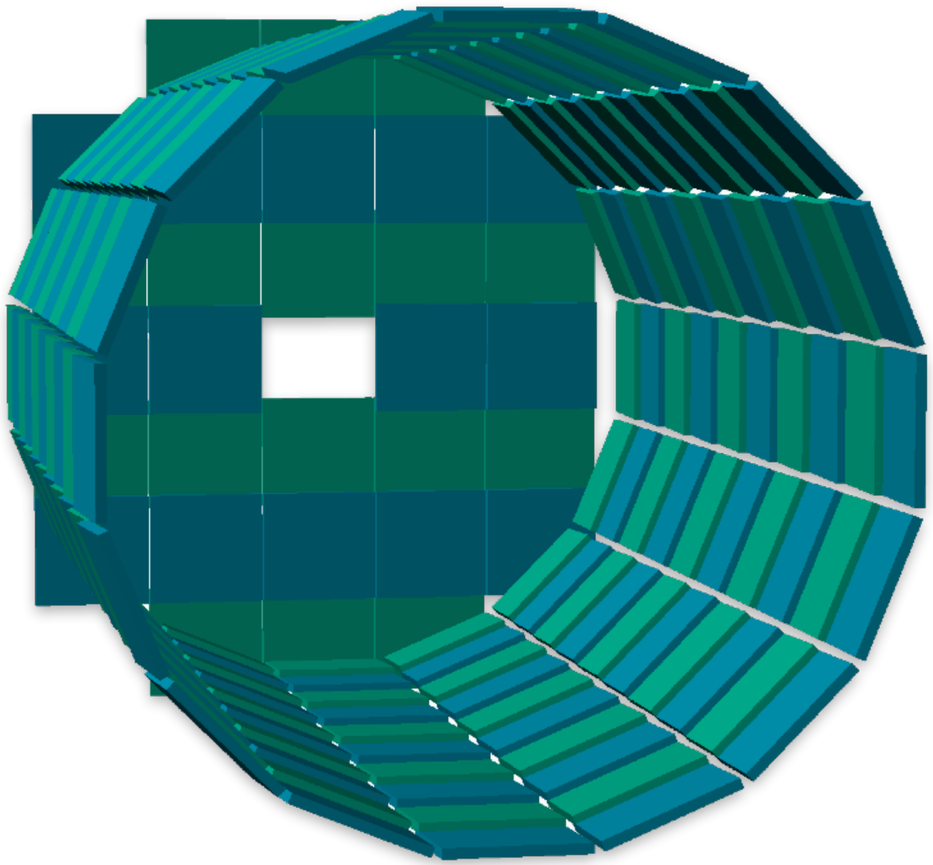




TDR for the PANDA Barrel TOF, July 4, 2018

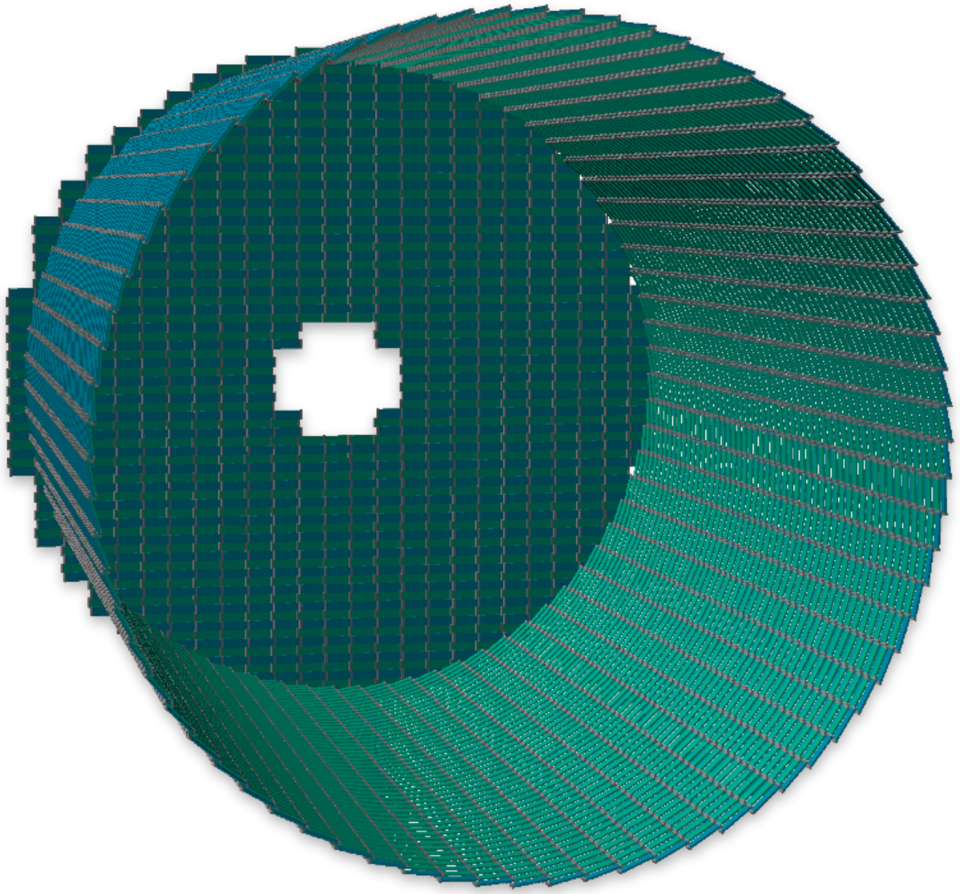
Two options for the TOF barrel of SPD (σ_t<70ps)

mRPC option



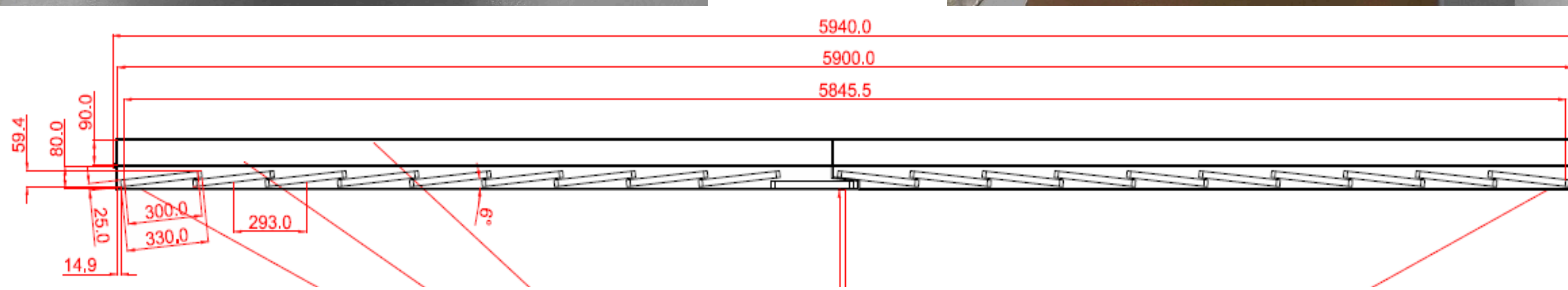
- Chamber size: 35 x 33 x 2.5 cm^3,
- 24 strips per chamber, strip: 35 x 1 cm^2
- Number of chambers (barrel + 2 x endcap):
  - 160 + 2 x 30 = 220
- Number of channels = 10.6k

Plastic scintillator option

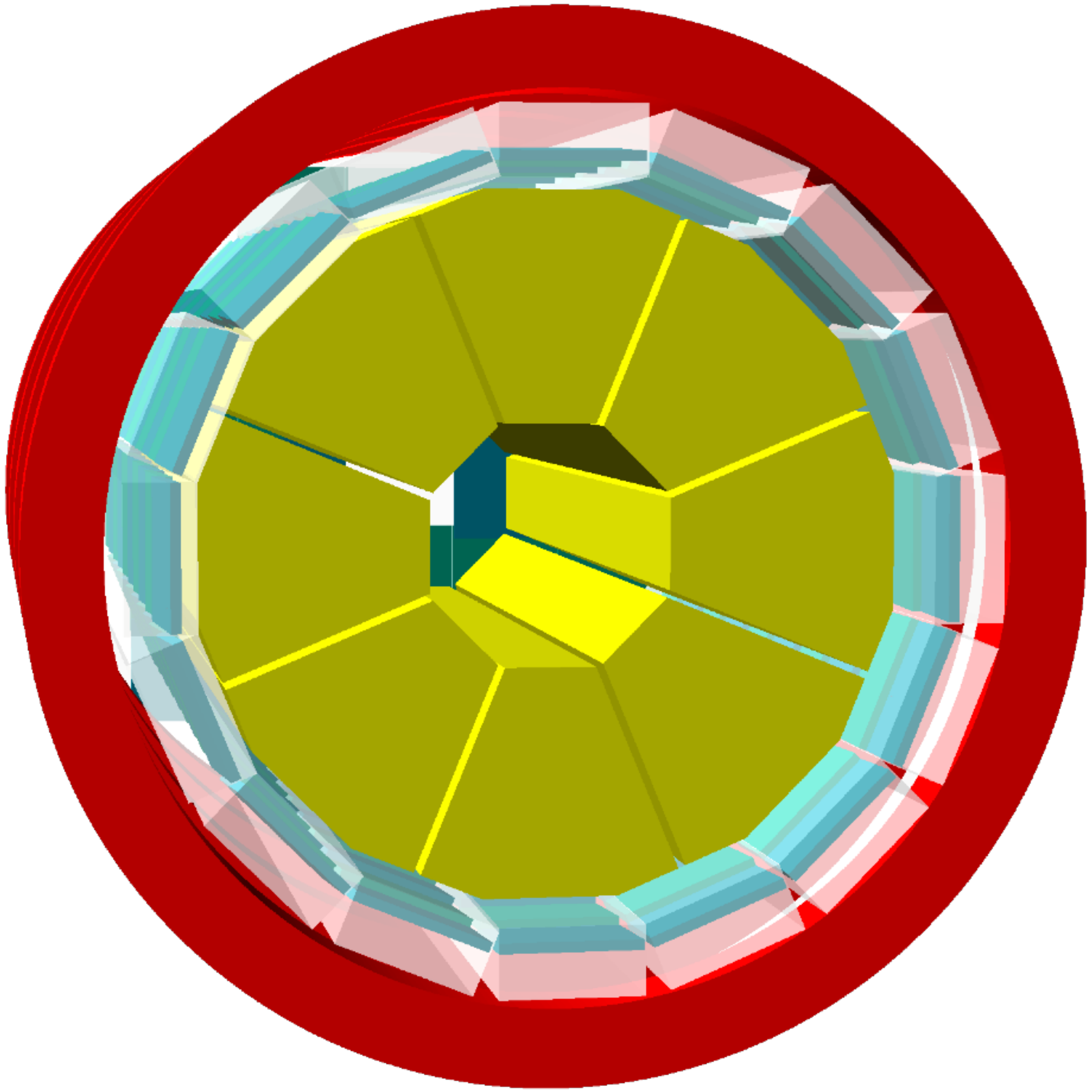


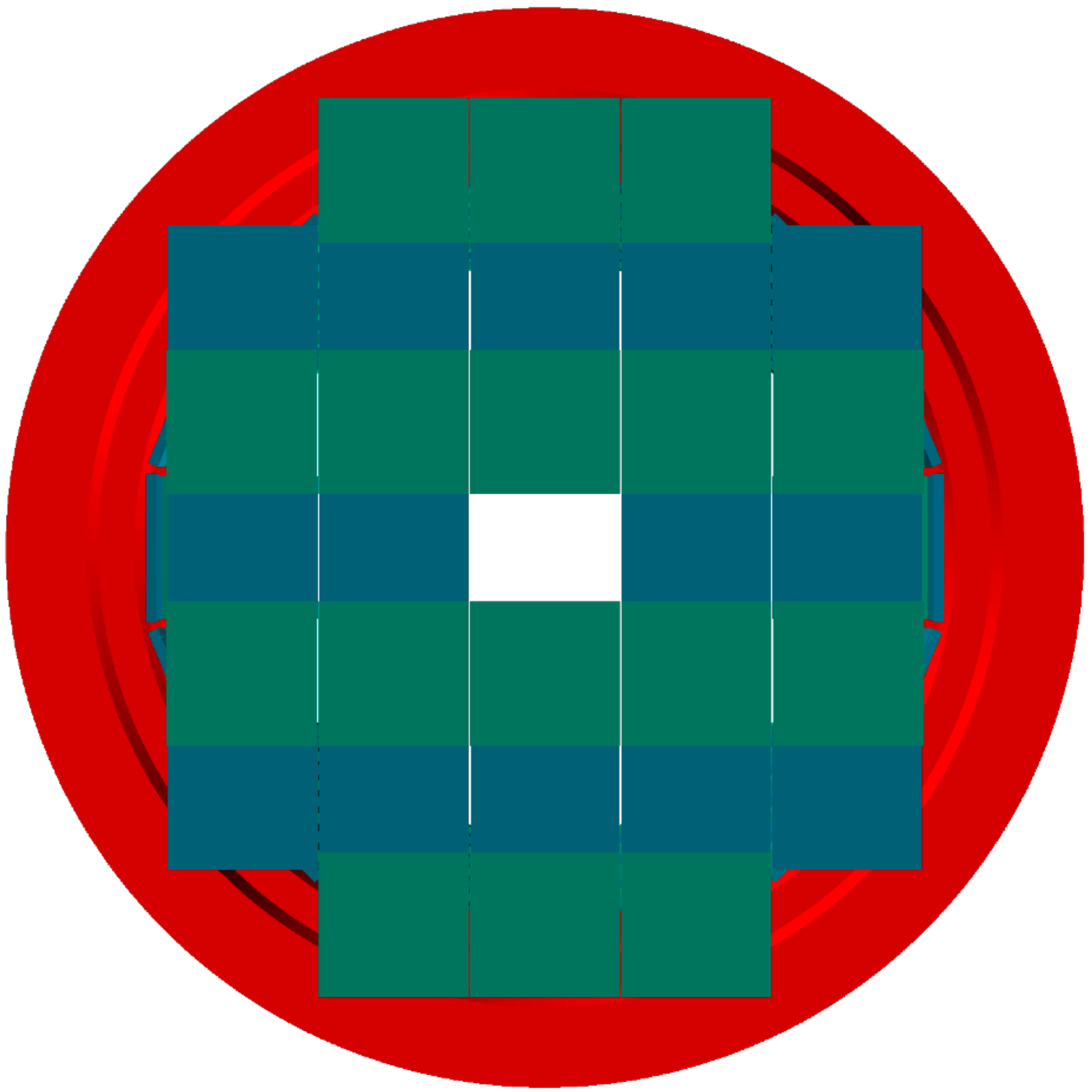
- Tile size: 9 x 3 x 0.5 cm^3
- 4 SiPMs (3 x 3 mm^2) at each end
- Number of tiles (barrel + 2 x endcaps):
  - 7.3 + 2 x 1.4k = 10.1k
- Number of channels = 20.2k

Assembling room for the MRPC barrel of MPD



Mechanics issues of the MRPC option for TOF/SPD

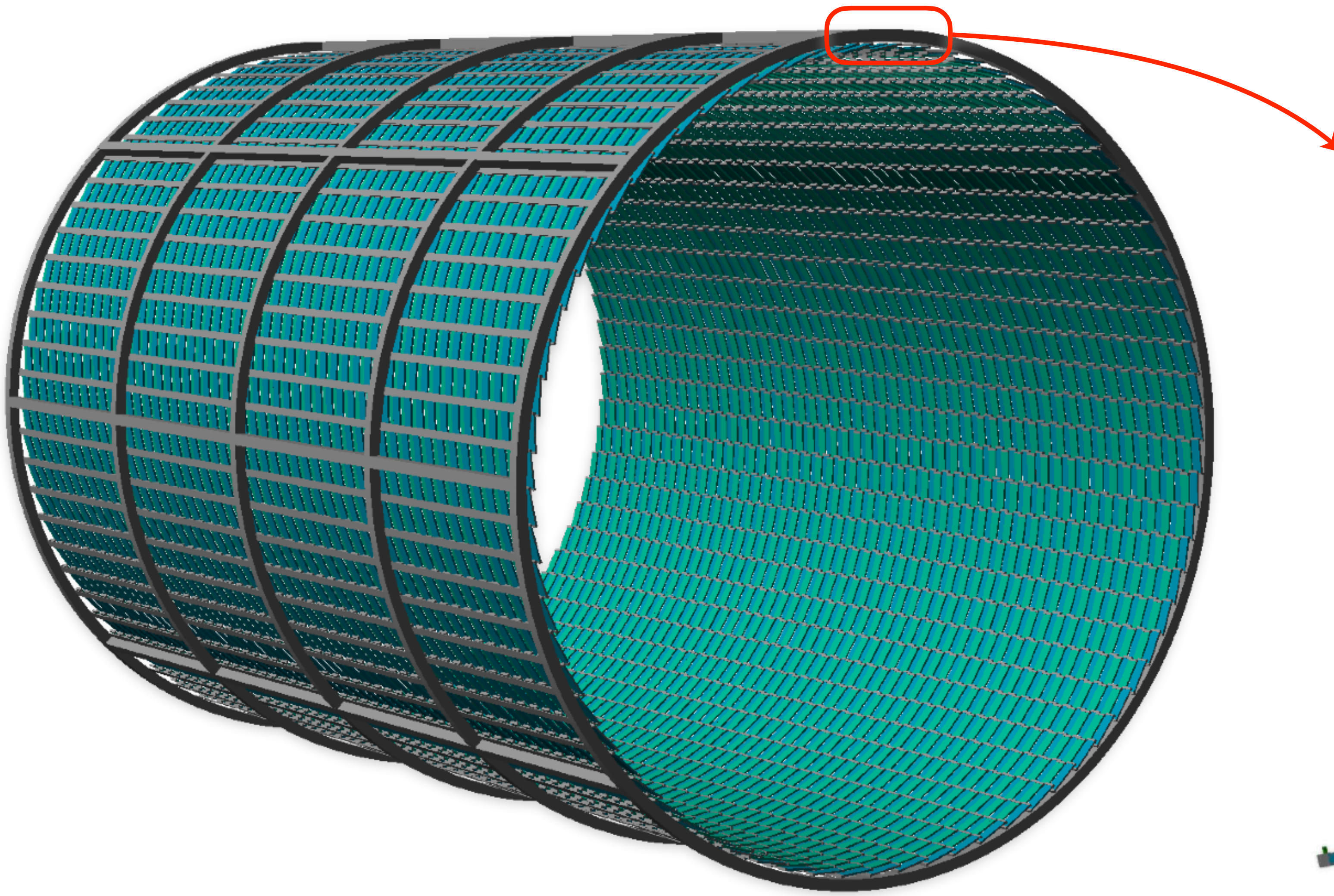




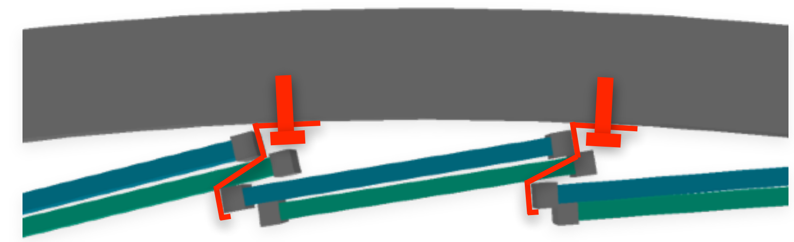
- Module takes 17cm distance radially → no space for another PID detector

- To be removable, the diameter of the TOF end-cap must be smaller than the one of the magnet coil
- Chambers have to be inside the Al box
- Either large dead regions or conflict with coils

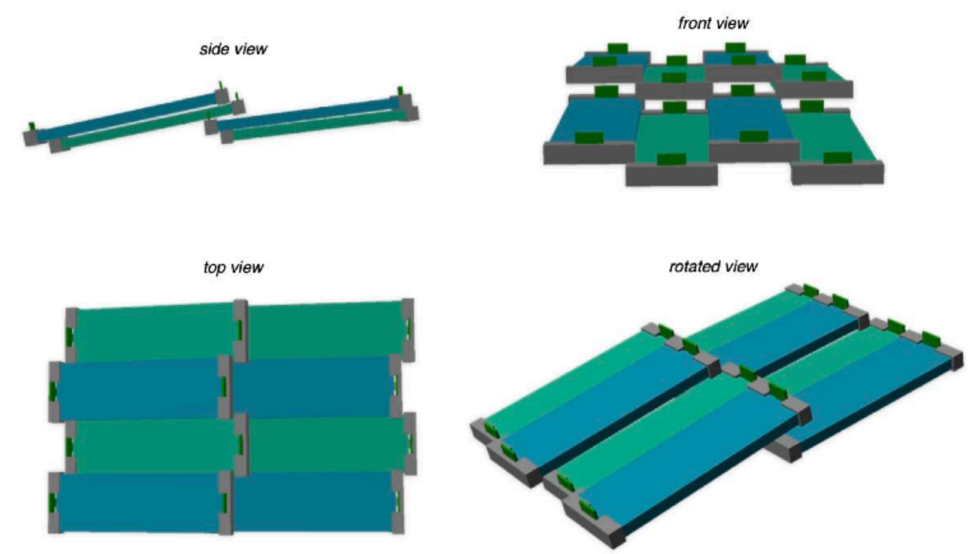
Plastic scintillator option for TOF/SPD



Brackets for fixation



Alignment of tiles without dead zones



- V_{tile} = 9cm x 3cm x 0.5cm = 13.5 cm^3
- ρ_{tile} = 1.032 g/cm^3 → m_{tile} = 13.9g
- m_{barrel} = 7.3k x 13.9g = 101kg

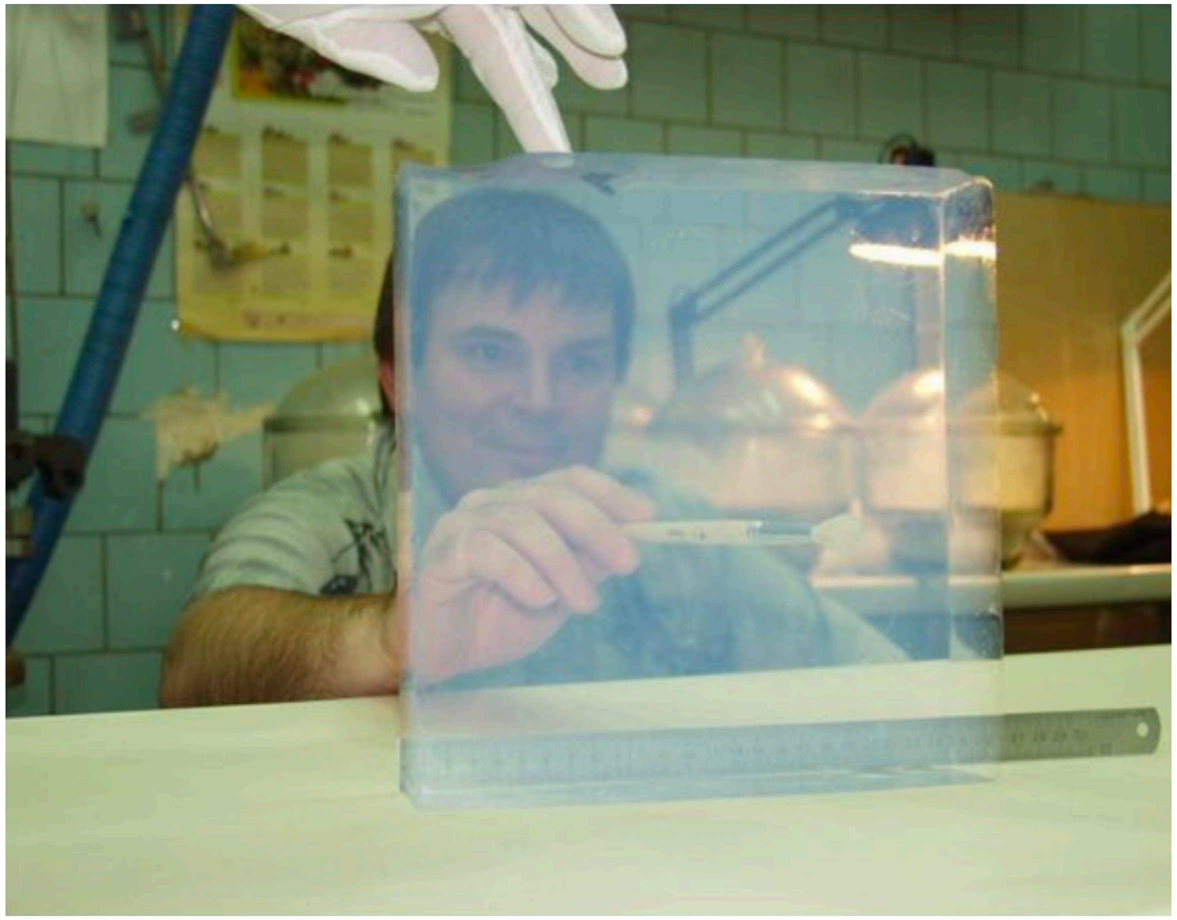
Two options for TOF (pros & cons)

MRPC	SciTil
sophisticated production procedure	assembling is fast and easy
requires gas flow, HV (trips)	easier to maintain (no gas, only LV)
takes radially 17cm (MPD), no way for Aerogel	can be squeezed within ~6cm, space for Aerogel
rectangular shape, large size (inconvenient for round end-caps)	small tile ⇒ can fit cylindrical shape
rad. length ≈ $0.14X_0$ *(MPD)*	rad. length ≈ $0.02X_0$
σ_t is independent of l_{strip}	σ_t drops exponentially with l_{tile}
S = pitch x length = 1.25cm x 40cm = 50cm^2 $N_{channel} \approx 10k$	S = pitch x length = 2.9cm x 9cm = 26cm^2 $N_{channel} \approx 20k$
not sensitive to radiation	sensitive to radiation
well established technology (MPD, BM@N)	requires R&D

- Both options are able to provide the resolution of ~60ps
- Applying different options for barrel and end-caps will double expenses/efforts for: DAQ, Power supply, Slow control, calibration & analysis

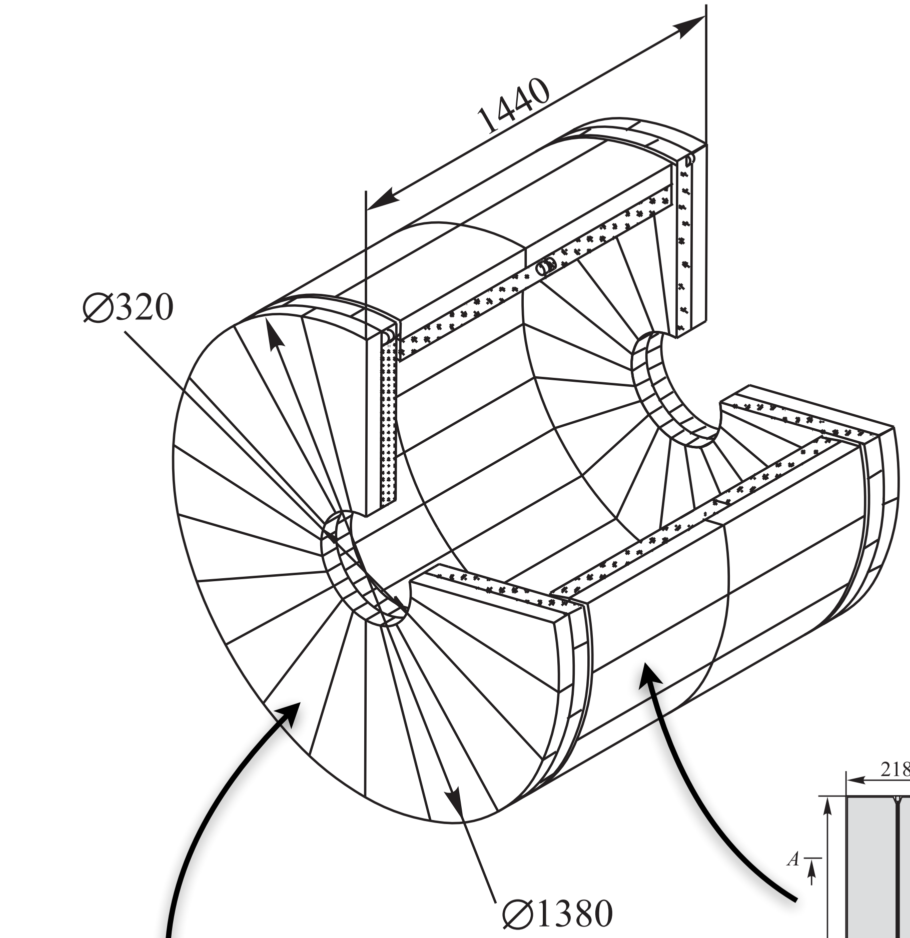
Aerogel detector

- Particle Identification via Cherenkov radiation
- SPD seminar, E.Kravchenko, INP, Novosibirsk on Oct 12



Система АШИФ детектора КЕДР

Детектор КЕДР, ФЭЧАЯ 2003 т.44 вып.4



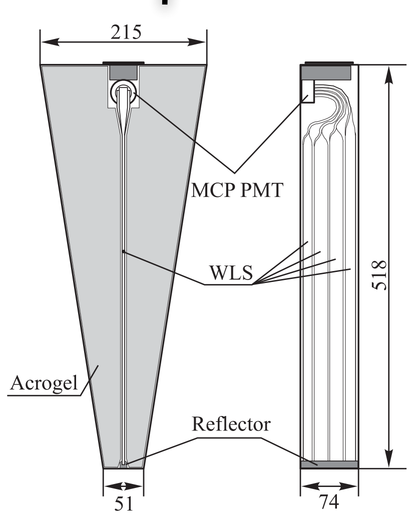


Рис. 16. Торцевой счетчик

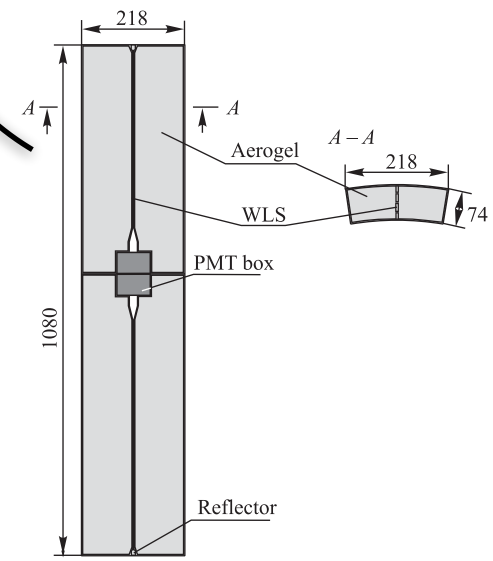


Рис. 17. Два баррельных счетчика в одном корпусе

Таблица 7. **Основные параметры системы АШИФ**

Телесный угол системы	$0{,}96 \times 4\pi$
Число слоев	2
Число счетчиков в слое	80
Показатель преломления аэрогеля	1,05
Диапазон импульсов π/K-разделения, ГэВ/c	0,6–1,5
Количество вещества для нормальной частицы	$0{,}24X_0$
Объем аэрогеля, л	1000

- ФЭУ на основе микроканальных пластин (МКП) с мультищелочным фотокатодом. Производители: ОАО "Катод" и ЗАО "Экран ФЭП” (Новосибирск). H=17мм, ∅=31мм
- Переизлучатель спектра: 150мг BBQ на 1кг ПММА, толщина 3мм. Спектр: (280-450)нм → 500нм
- Среднее число фотоэлектронов после 5 лет работы падает на 34% составляет 6р.е.
- Временное разрешение АШИФ на пионах с p=0.86ГэВ составляет σ_t=2нс

Система АШИФ детектора КЕДР

Детектор КЕДР, ФЭЧАЯ 2003 т.44 вып.4

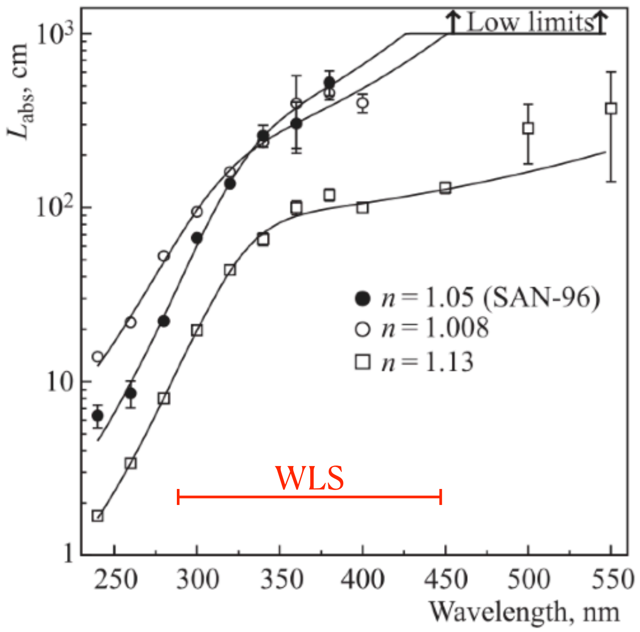


Рис. 18. Измеренная зависимость длины поглощения в аэрогеле от длины волны света для разных аэрогелей

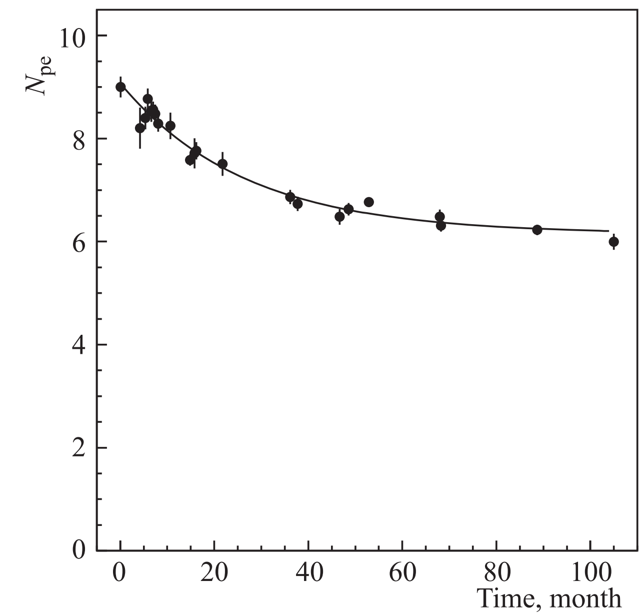


Рис. 21. Амплитуда сигнала (число фотоэлектронов) от космических мюонов как функция времени

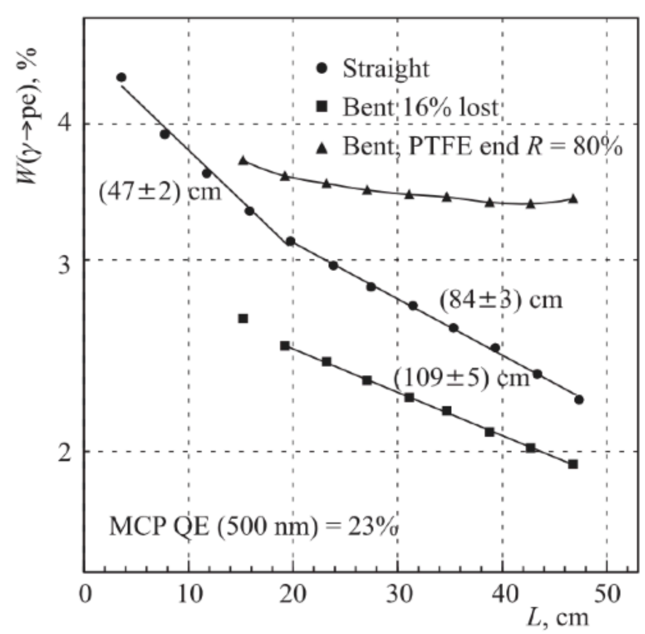


Рис. 19. Измеренная вероятность преобразования фотона в фотоэлектрон ($W(\gamma \to$ pe)) шифтера в зависимости от расстояния до фотоприемника и длина ослабления (число рядом с кривой)

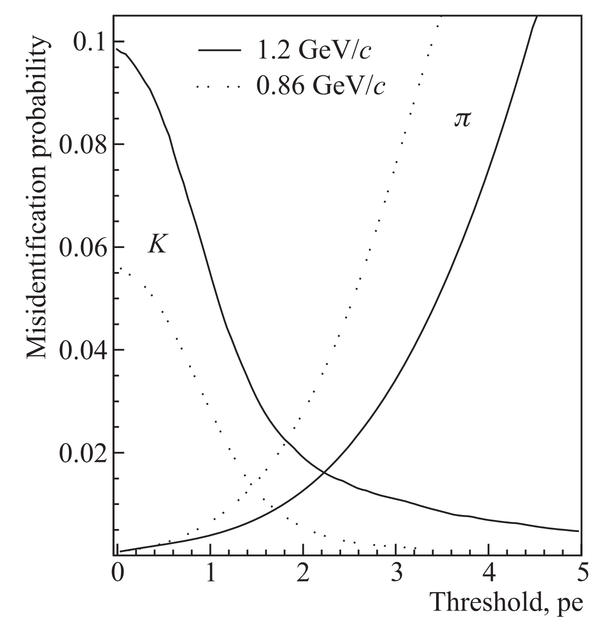
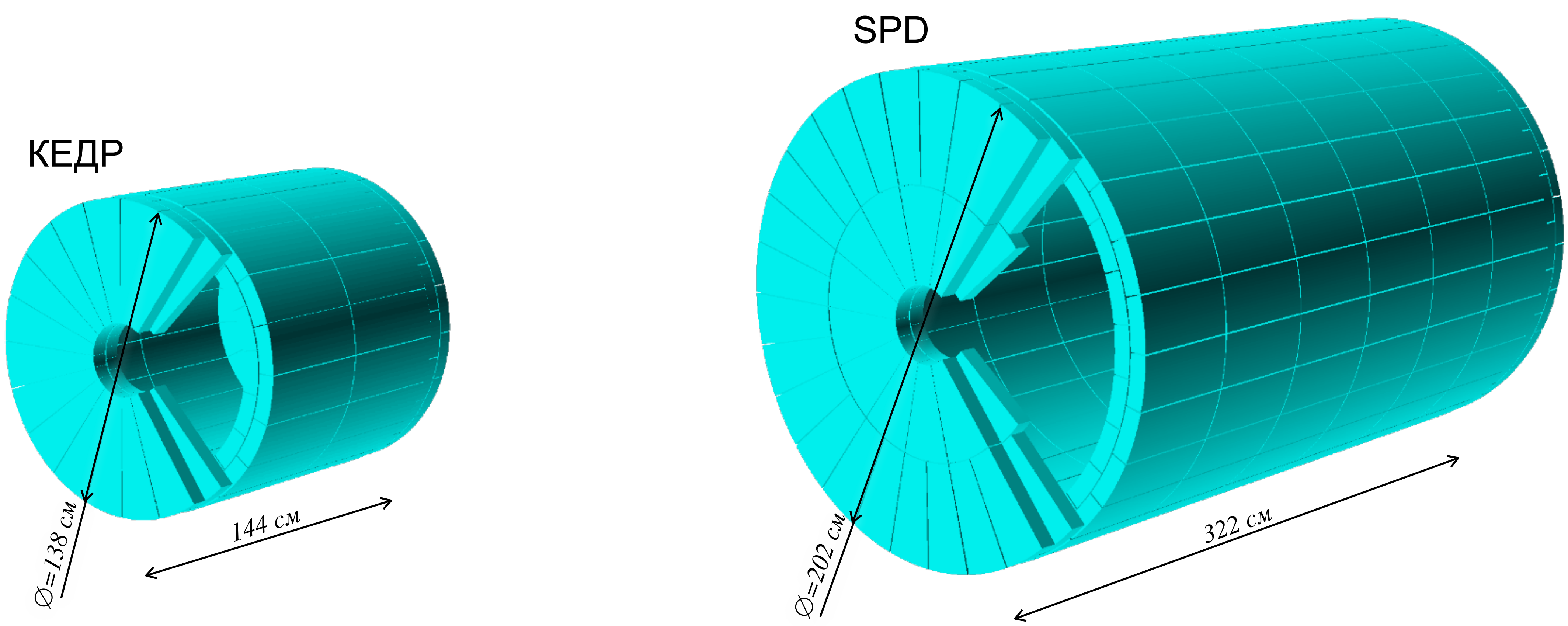


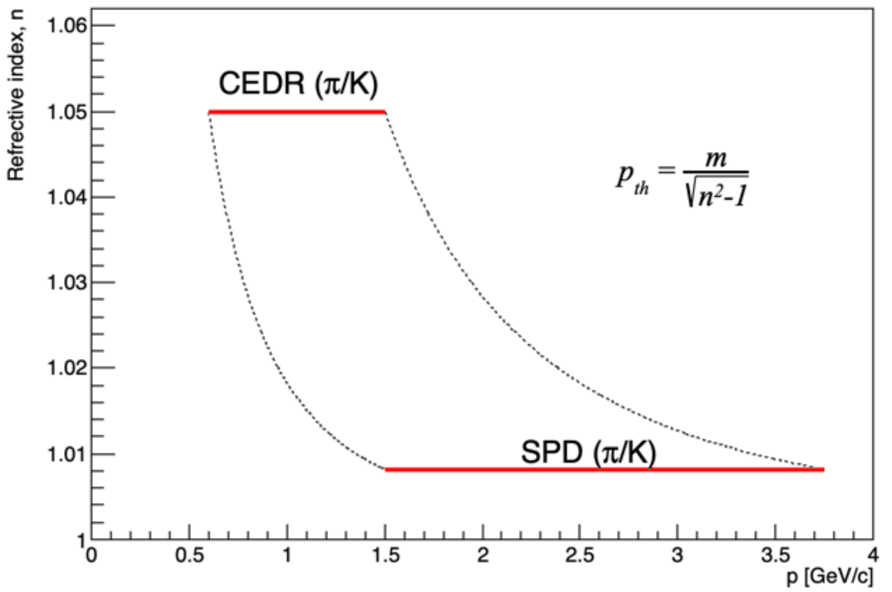
Рис. 20. Измеренная зависимость ложной идентификации пионов и каонов от амплитуды для импульсов $P = 0{,}86$ ГэВ/c и $P = 1{,}2$ ГэВ/c

Аэрогель в **SPD** по образу детектора КЕДР



	КЕДР	SPD
# счетчиков (barrel+endcap)	80+80=160	336+168=504
# ФЭУ (barrel+endcap)	160	504
$V_{аэрогель}$	1.1м^3	3.5м^3

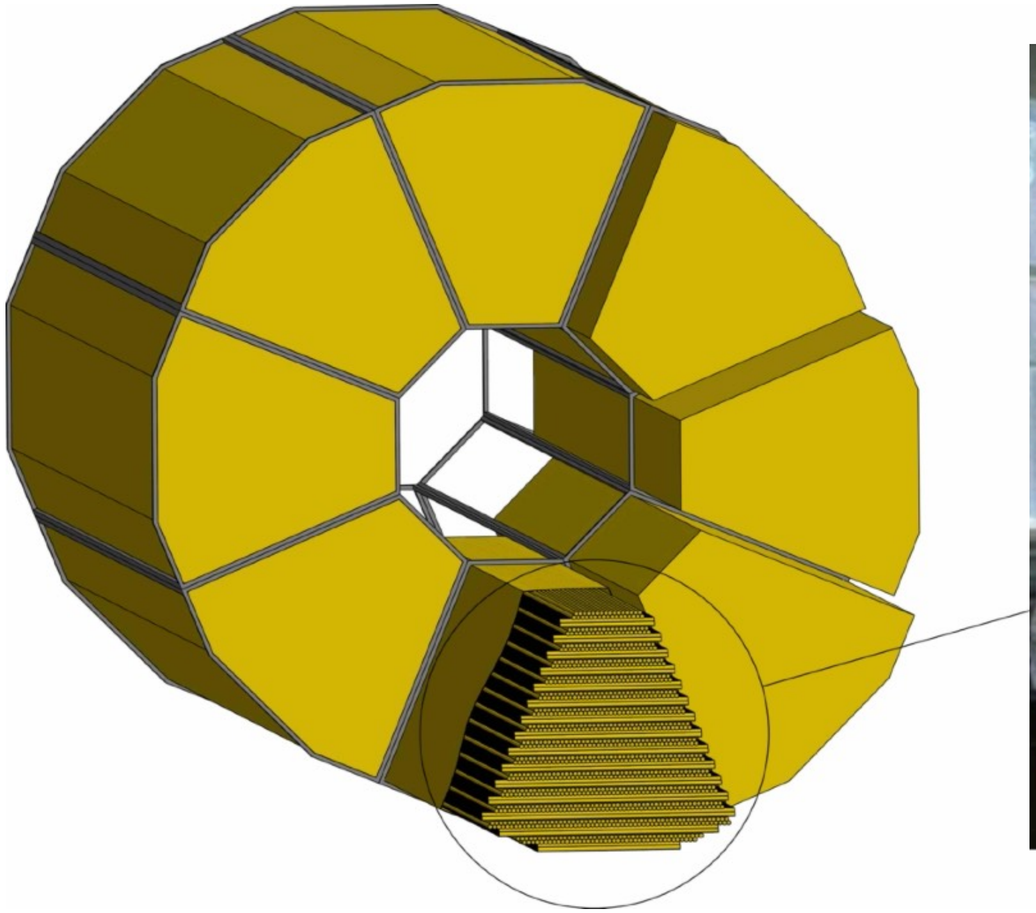
- Эффективность срабатывания 1-го слоя АШИФ (КЕДР):
  - 2005г: 99% (торцевые), 88% (барель)
  - 2010г: 97% (торцевые), 78% (барель)



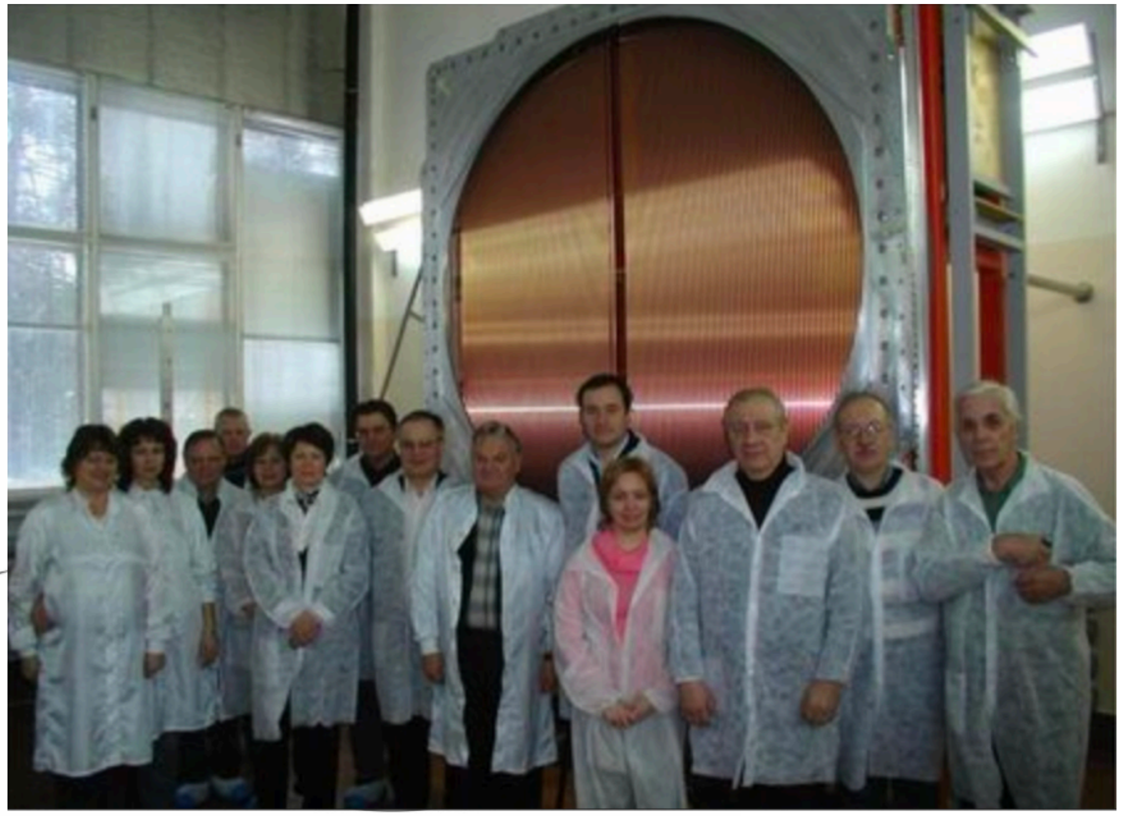
Straw detector

- Primary purpose is tracking, σ_x=150μm
- Particle identification via energy loss (*dE*/*dx*)

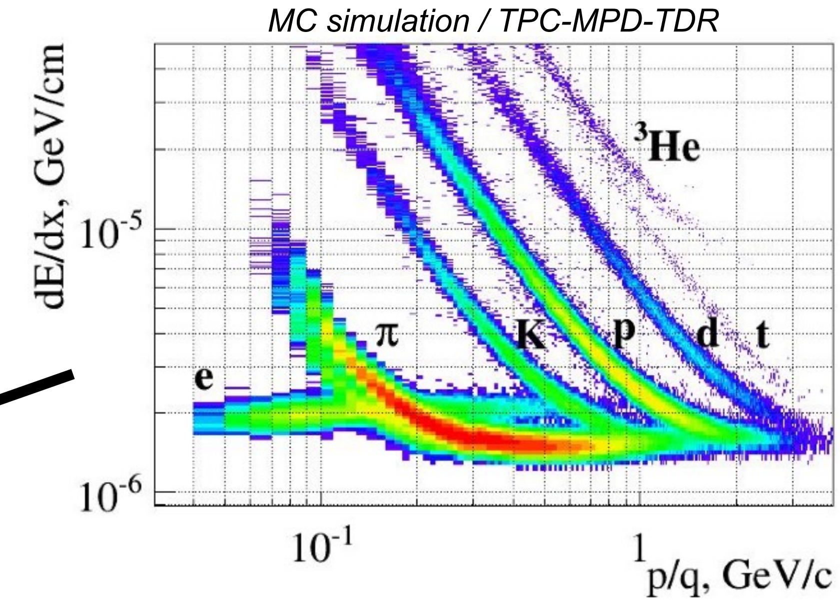
SPD



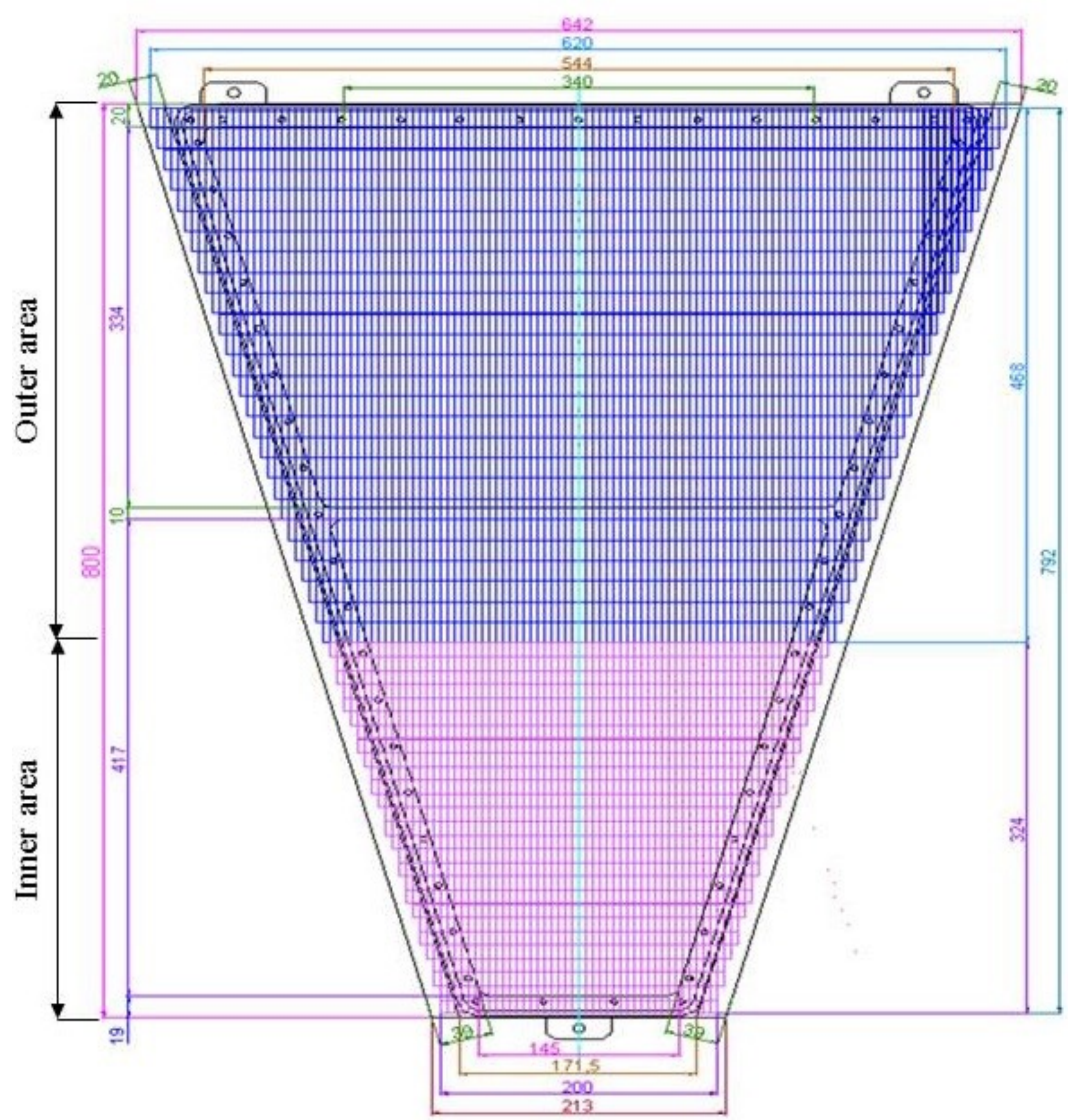
NA62



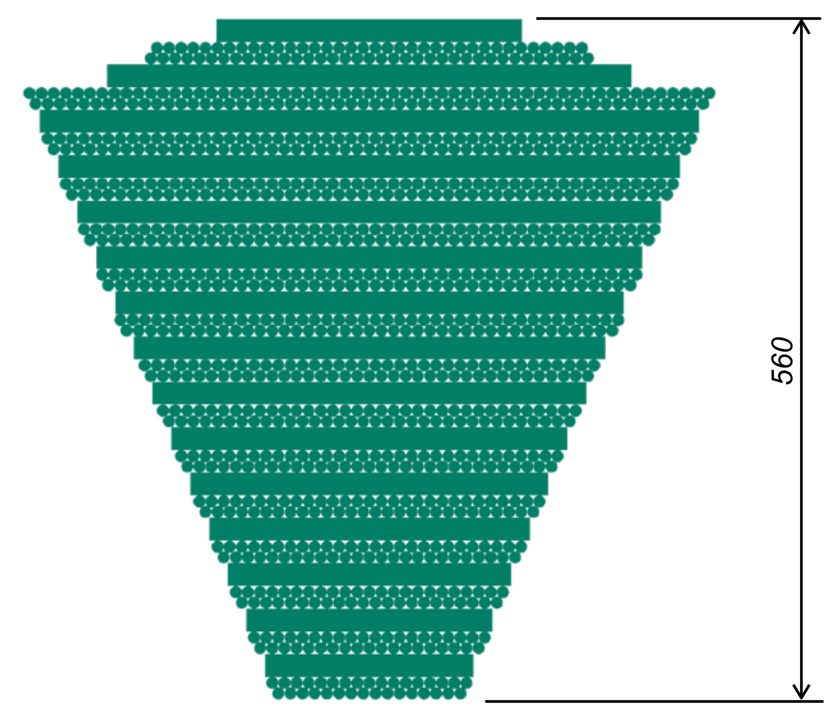
TPC vs Straw in respect of dE/dx analysis



TPC of MPD



Straw of SPD



Inner pads: S = 5mm x 12mm = 60mm²

Outer pads: S = 5mm x 18mm = 90mm²

∅=10mm straw: S = 78mm²

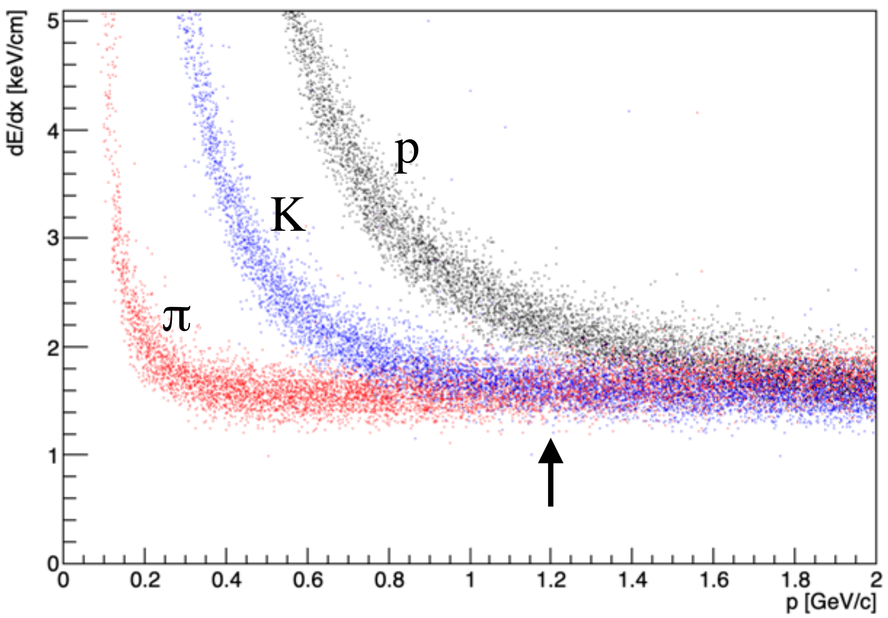
∅=5mm straw: S = 20mm²

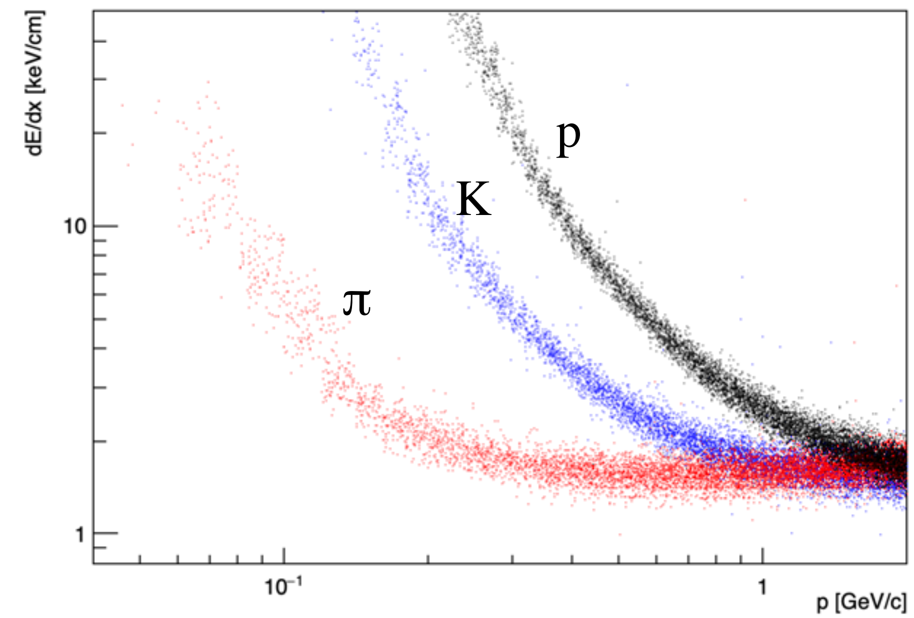
Maximum drift time 30 μs

Maximum drift time 150 ns

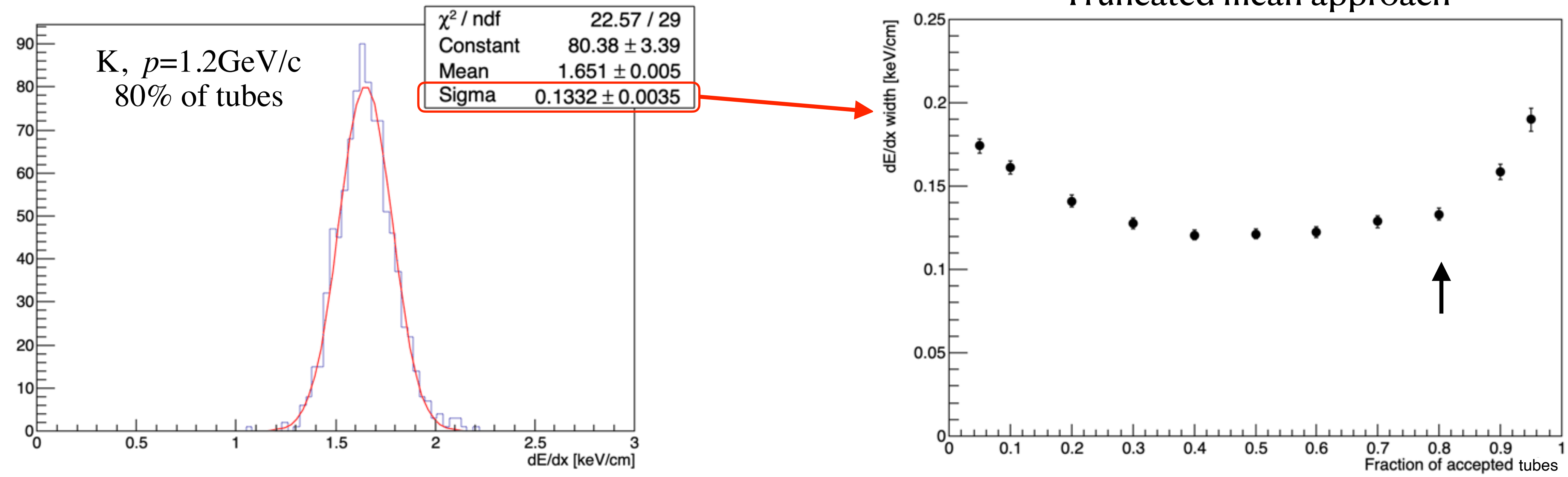
dE/dx analysis for Straw/SPD

file with 10k events produced by Andrei Maltsev on Nov 26

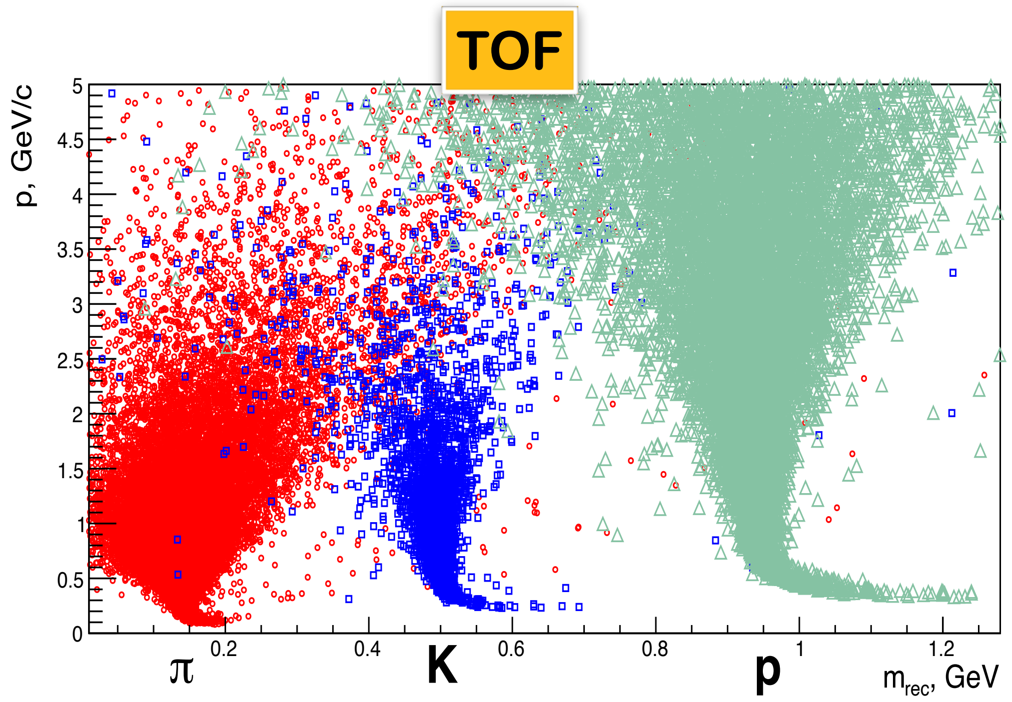


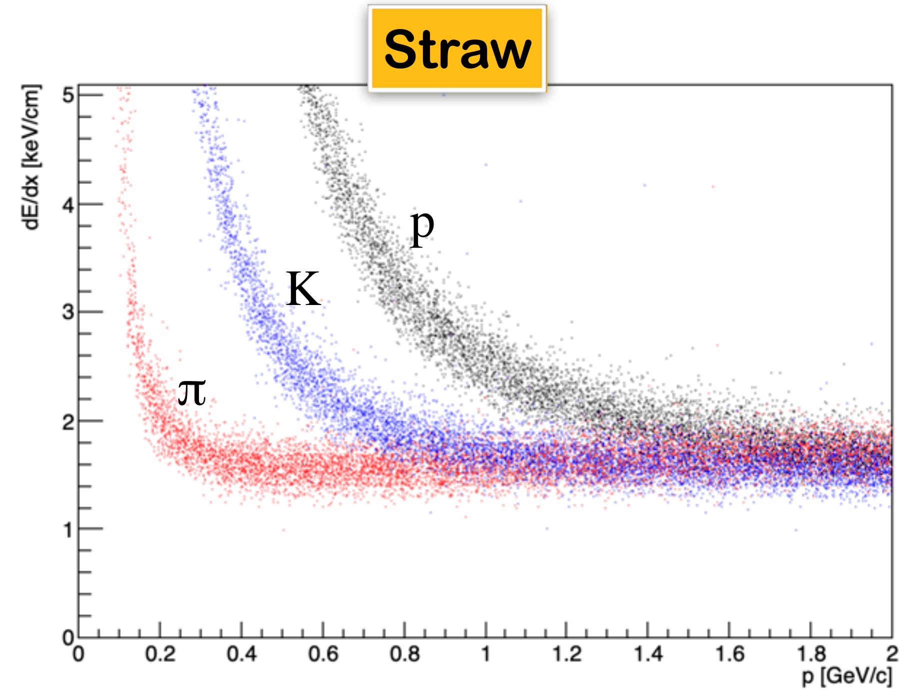


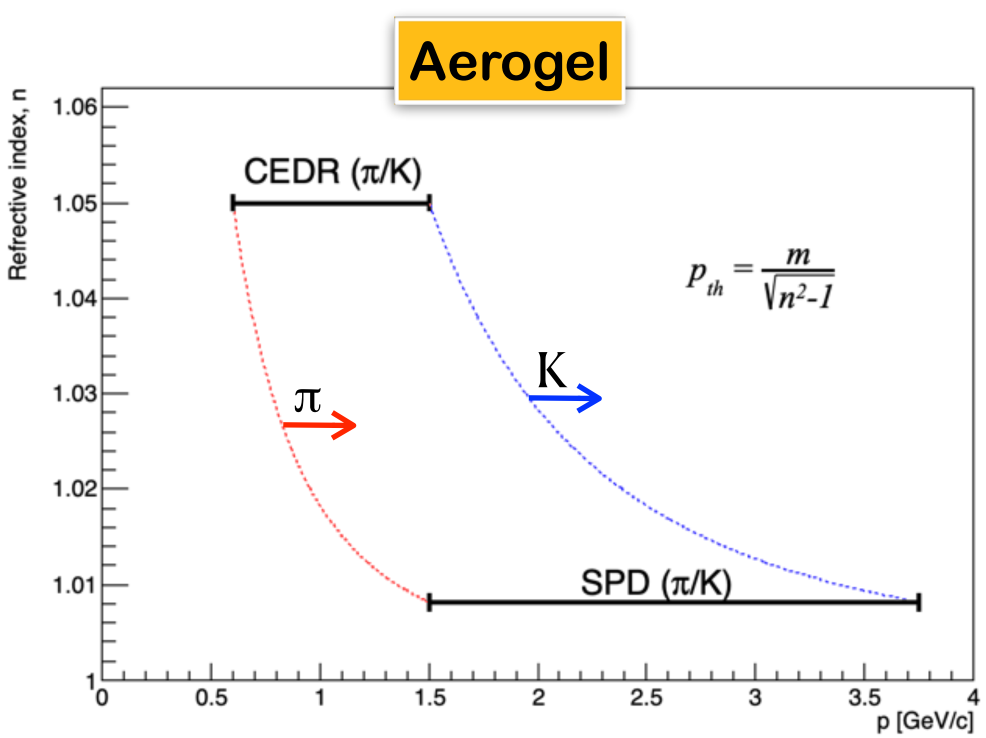
Truncated mean approach



Summary: PID analysis in SPD (π, K, p)





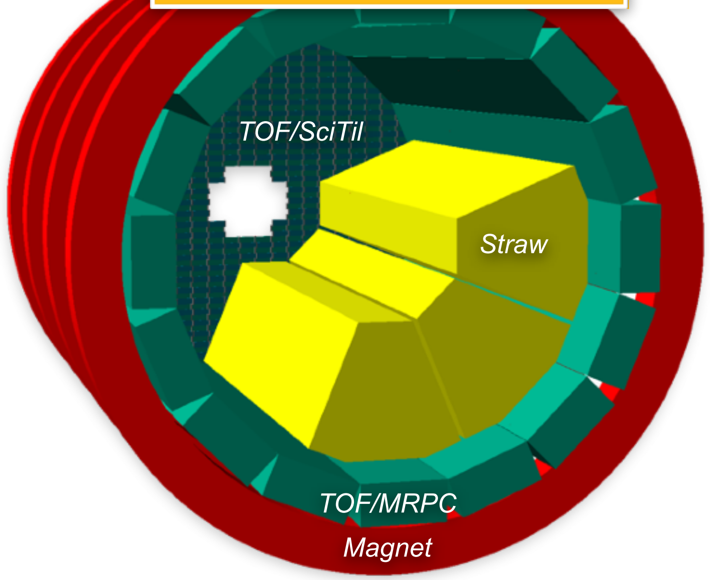


π/K separation

- Short tracks (R<1m) to be identified by straw up to 0.7 GeV/c
- Long tracks (R>1m) to be identified by straw+TOF up to 1.5 GeV/c
- tracks with p>1.5 GeV/c to be identified by aerogel (and straw?)

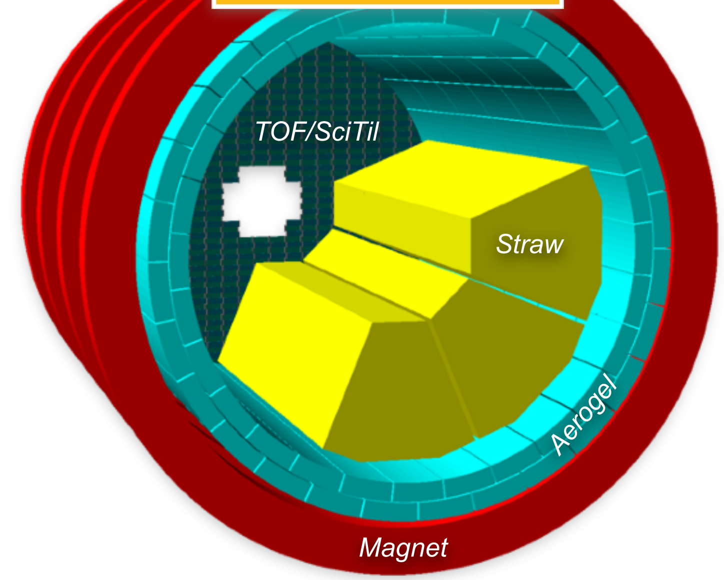
Summary: options for PID (TOF, Aerogel, Straw)

TOF/MRPC barrel



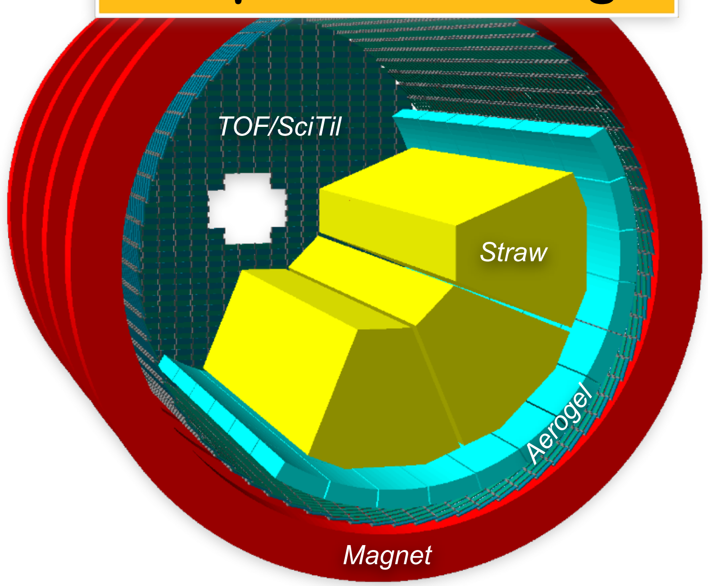
- Module takes 17cm radially (no place for other PID detector)
- Choice for TOF end-caps is still opens

Aerogel only



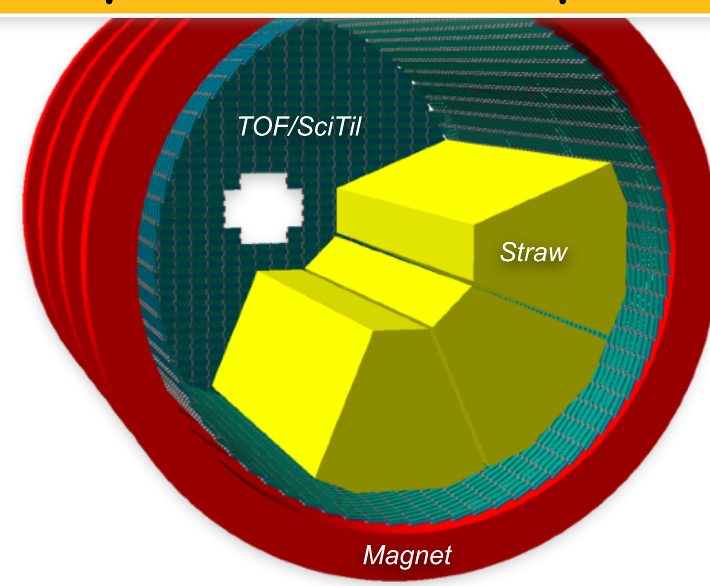
- Module takes 17cm radially (no place for other PID detector)
- Missing timing measurements in barrel

TOF/plastic + Aerogel



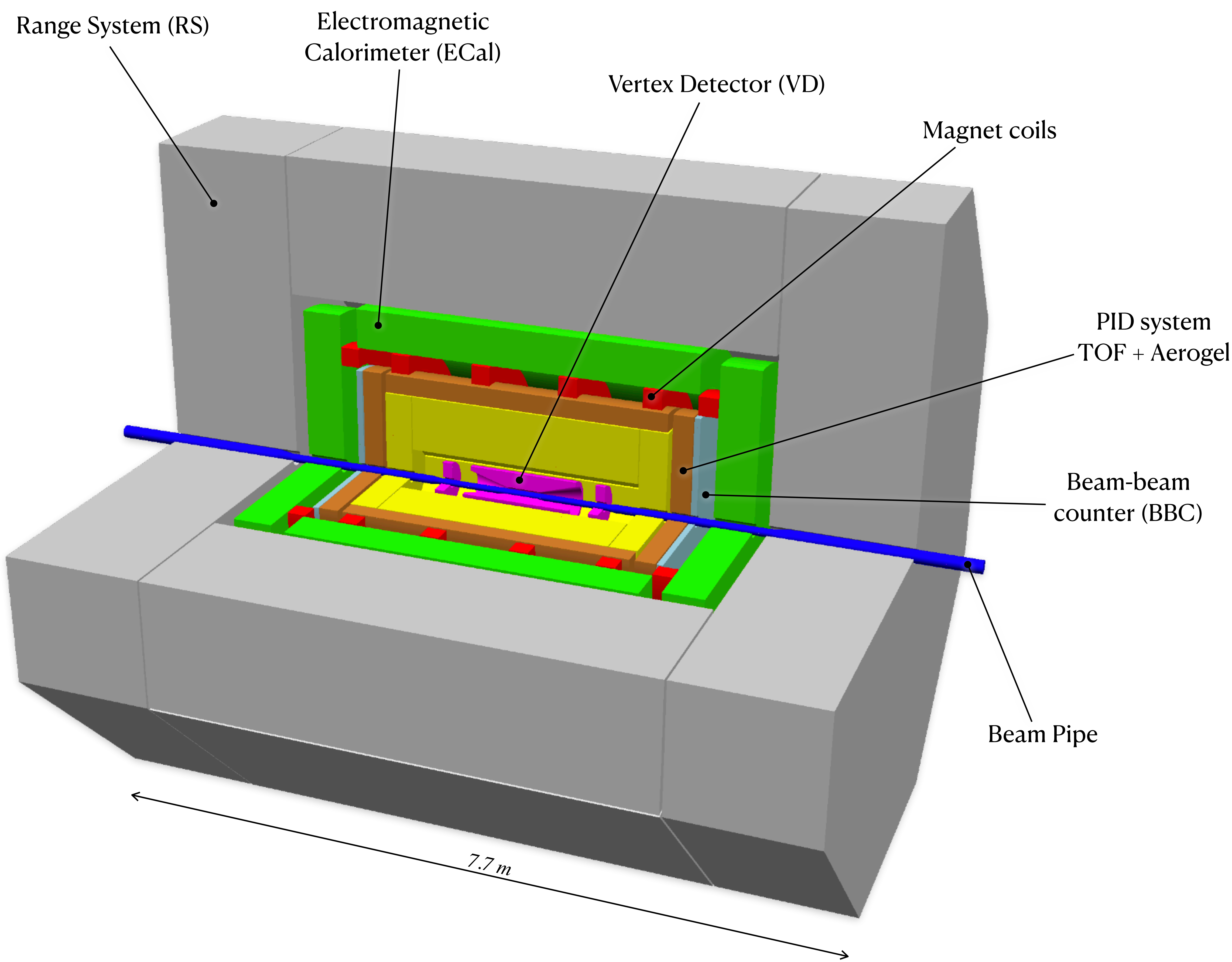
- The same choice of TOF for barrel and end-caps
- Lower thickness → lower efficiency for Aerogel

TOF/plastic + Straw expansion



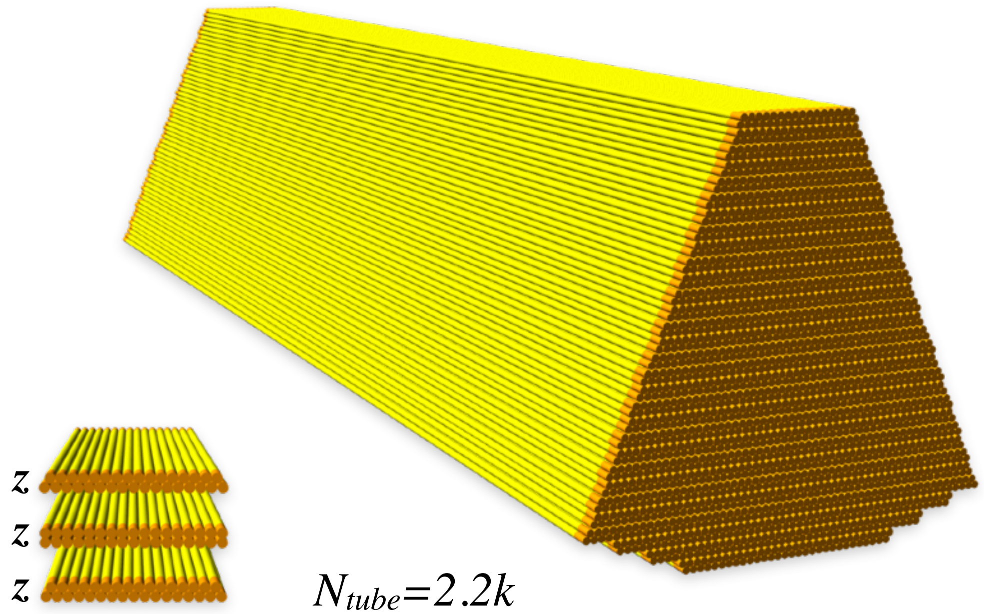
- The same choice of TOF for barrel and end-caps
- Improvement of dE/dx via increasing straw layers by 10

backup slides

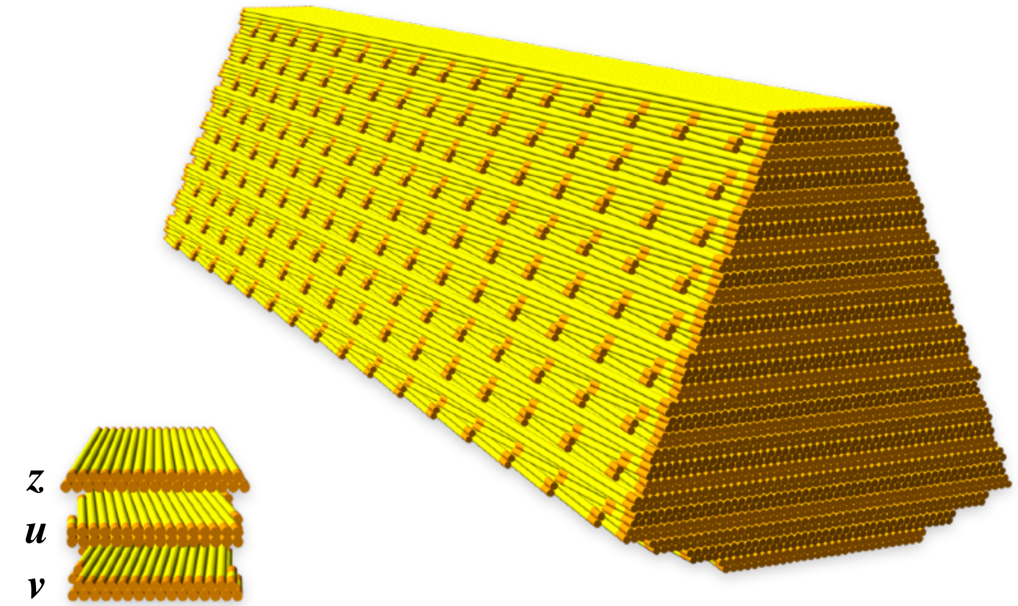

Range System (RS)
Electromagnetic Calorimeter (ECal)
Vertex Detector (VD)
Magnet coils
PID system TOF + Aerogel
Beam-beam counter (BBC)
Beam Pipe
7.7 m

Tube alignment for straw detector (30 double layers)

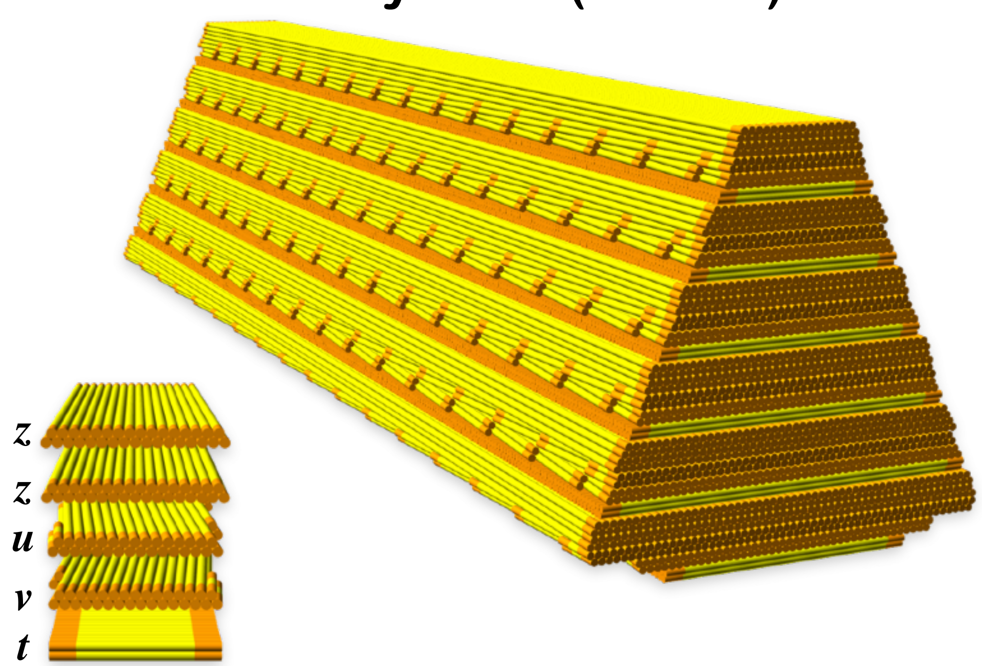
All tubes along z, 30x(Z)



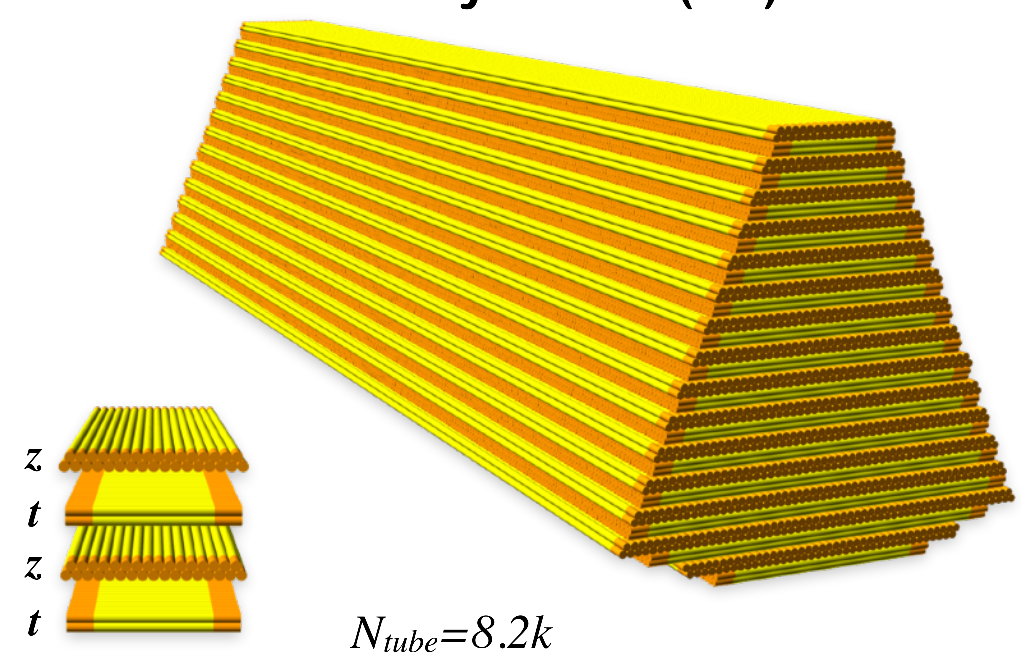
Layers 10x(ZUV)



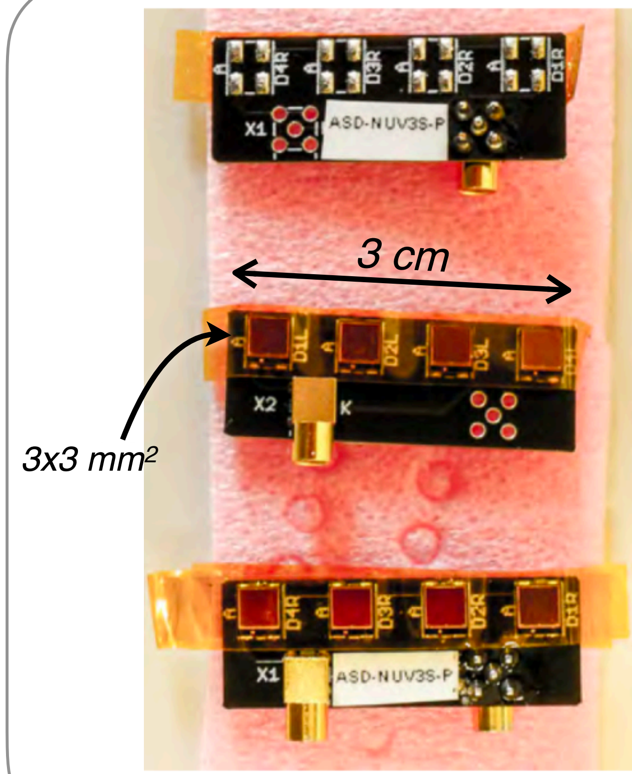
Layers 6x(ZZUVT)



Layers 15x(ZT)



Plastic scintillator option for TOF/SPD



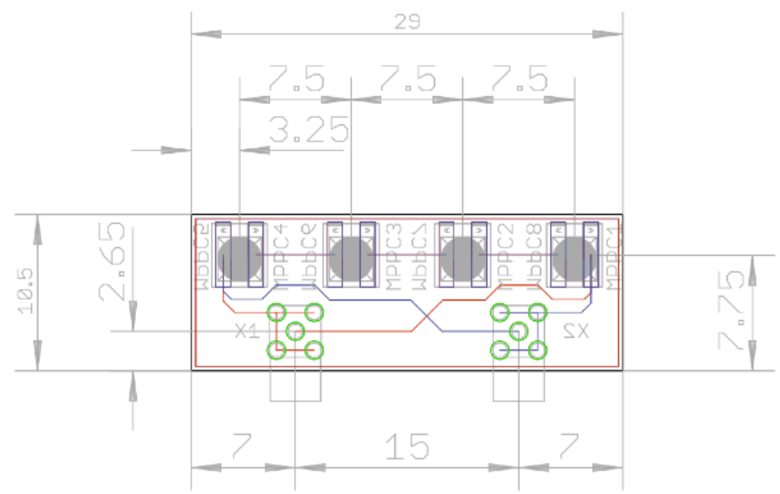
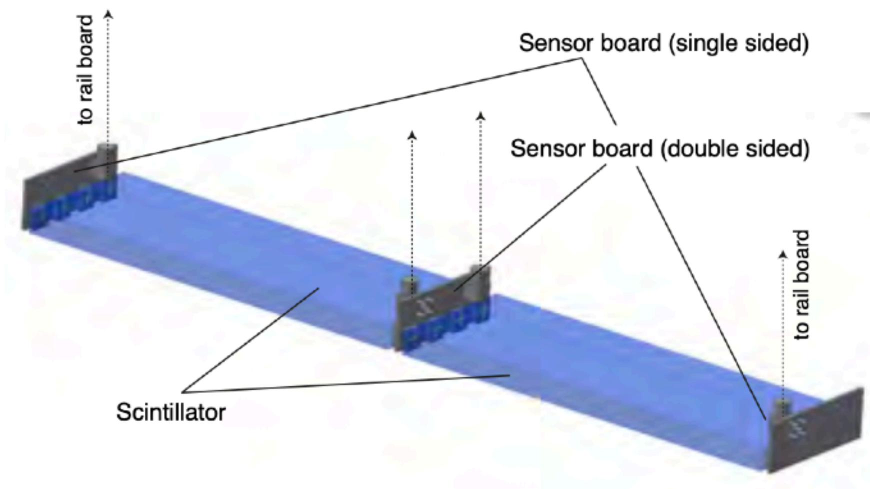


Figure 4.7: The layout of the sensor-board. 4 SMD-type SiPMs are soldered on one side. If the sensor board is to be used in the middle of two scintillators, the SiPMs are soldered on both sides. See also Fig. 4.10.

TOF for PANDA



- TOF of PANDA
- Tile cross section is 30x5 mm²
- 4 SiPMs 3x3 mm² each
- Fraction of light detected
  - (4x3x3)/(30x5) = 24%
- The resolution is 50 - 100 ps

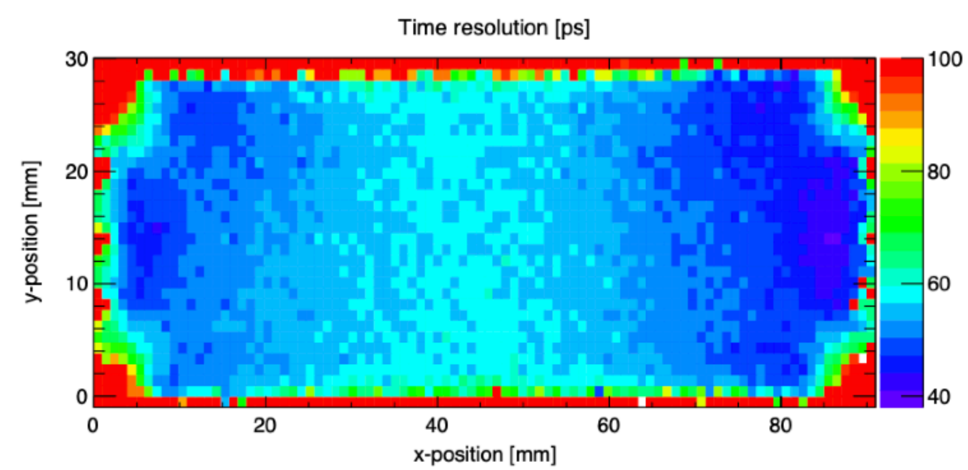
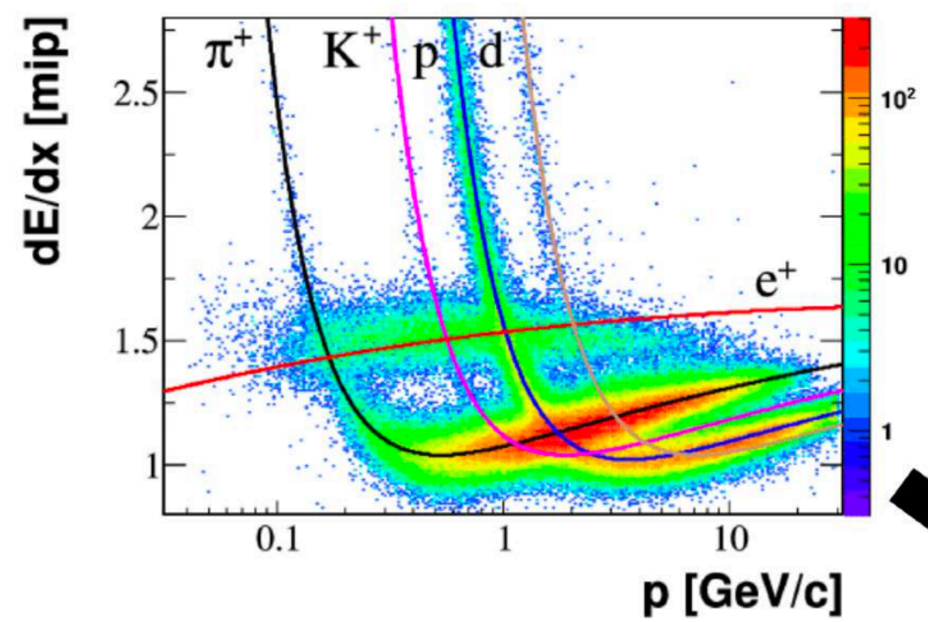


Figure 6.13: Time resolution obtained from a position scan of a $90\times30\times5\,\mathrm{mm}^3$ EJ-232 scintillator tile readout by Hamamatsu SiPMs attached to opposite sides (y-axis), 4 SiPMs in series per side.

Particle identification



- Energy loss measurement in Ar:CO_2 medium (90:10). Typical resolution 3-5%
- Intrinsic TOF resolution 115 ps. Can be useful up to 10 GeV/*c*
- Combined TOF-*dE/dx* analysis allows efficient identification in cross-over region of BB curves